Aeroplane Maintenance and Operation Series, Volume 12

STARTERS AND GENERATORS

AEROPLANE MAINTENANCE AND OPERATION SERIES

Compiled under the General Editorship of E. MOLLOY

VOL. NO.

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Aeroplane Maintenance and Operation Series, Volume 12

STARTERS AND GENERATORS

DEALING WITH THE OPERATION AND MAINTENANCE OF ROTAX STARTERS AND GENERATORS, B.T.H. AND ARMSTRONG-SIDDELEY STARTERS, AND NOTES ON THE CONSTRUCTION, OPERATION, AND MAINTENANCE OF GAS STARTERS

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COMPILED BY A PANEL OF EXPERTS

WITH SIXTY-SEVEN ILLUSTRATIONS

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PREFACE

AERO-ENGINE starting devices are a comparatively recent refinement, due partly to the need to economise in weight—batteries and motors are heavy—and partly to the existence, in the airscrew, of something convenient to get hold of, serving the same purpose as the motor-crank handle.

To-day when one cylinder may develop as much horse-power as a complete engine of, say, seven cylinders used to, and most engines are geared up relative to the airscrew, "swinging the prop" on a cold morning would be a formidable undertaking. Consequently other means of starting have now become the usual practice in large engines.

A very large proportion of the present-day aero engines are provided with either Rotax or B.T.H. starters, and it is for this reason that we have taken these leading makes as the subject-matter of the present volume.

Present-day starters are roughly of two types: the electric starter, which is similar to that used on motor cars and consists of an electric motor driven by a 12- or 24-volt battery and connected to the crankshaft through the hand-turning gear; and the inertia starter, in which use is made of the energy stored up in a small flywheel by gradually building up its speed and then liberating this energy on the engine. This latter type of starter may be operated by hand turning or by an electric motor.

In each case the principle of operation of the particular starter has been clearly described, as it has been realised that for efficient servicing a clear understanding of the principles of operation are highly desirable if not absolutely essential.

Instructions are also given for dismantling, servicing, reassembling, and testing, and the information given will, we believe, be of direct utility when any practical problem is encountered during the maintenance, servicing, or inspection of power-driven aircraft. Many useful photographs and diagrams have been included.

We are greatly indebted to Messrs. Rotax, Ltd. and the B.T.H. Co. for their assistance in placing technical information at our disposal, and for the loan of illustrations.

An additional section is included dealing with the gas starter in which a compressed-air cylinder is used. Gas starting of aero engines is accom-

plished by utilising a combustible mixture of fuel and air under pressure as the initial means of rotating the crankshaft of the engine.

The type of gas starter described is adaptable to aeroplanes with any number of engines.

E. W. K.
E. M.

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STARTERS AND GENERATORS

ROTAX ECLIPSE TYPE E160 STARTERS

THE Rotax Eclipse Direct-cranking Electric Type E160C starter is intended for fitting on engines equipped with 6-in. S.A.E. diameter mounting flange.

The direct-cranking starter assures instantaneous, continuous cranking of the engine, and is operated from a 12- or 24-volt battery circuit. It can be obtained either for clockwise or anti-clockwise rotation, rotation being determined by viewing the starter jaw. A manual cranking means is provided for emergency use.

The starter consists of an electric motor, reduction gearing, an automatic meshing and demeshing mechanism, and adjustable torque overload release, and a hand-cranking device.

Operation Cycle

When electrically operated, the closing of the battery circuit to the starter actuates the electric motor, the armature shaft of which is fitted with a driving pinion. The motor torque is transmitted at a ratio of 90 : 1 through a gear reduction unit to the driving barrel which contains the torque overload release, a spring adjustable multiple-disc clutch. The adjustable clutch is set so as to transmit the proper torque or driving power to a screw shaft which in turn projects the starter jaw into mesh with the engine jaw.

The setting of the clutch is such that no damage will occur should the starter be engaged to the engine when it is not free to turn over, due to climatic conditions, etc. A simple mechanism controls the engagement of the starter jaw to the engine, so that it does not commence to rotate until it is fully engaged.

The design of the starter engaging jaw provides for instant demeshing upon the starting of the engine.

The operation cycle, when manually operated, is identical with the electric starting, except that only a part of the gear reduction is employed, due to the difference in speed of hand and motor cranking. The manual

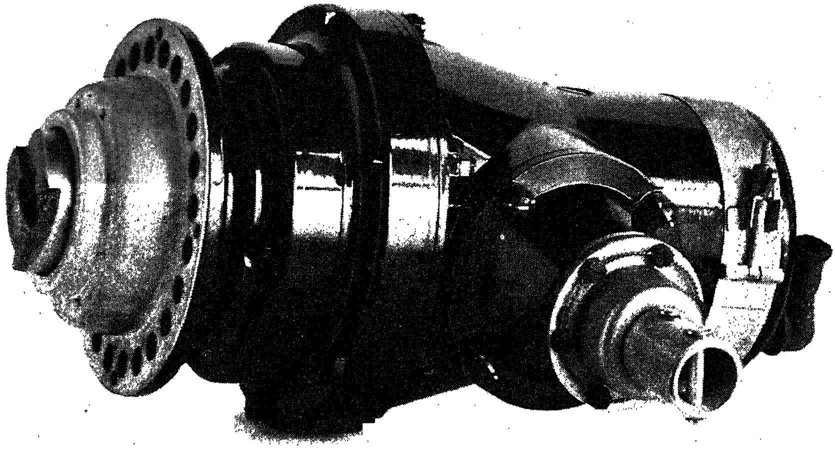

Fig. 1.—Rotax Eclipse type E160C starter

energy is transmitted at an 18 : 1 ratio through the driving barrel, and thence the same as with the electrically operated unit.

Installation

Before mounting the starter to the engine, remove the dust cover which is mounted on the forward end of the starter ; this cover is provided for shipping and handling of the starter only.

The type E160C starter is applicable to engines having the standard 6-in. diameter S.A.E. mounting flange. Six studs are located in this flange on a 5-in. bolt circle.

Before mounting the starter to the engine, remove the crankcase plate covering the opening to which the starter is to be applied. Examine the end of the crankshaft, and ascertain if the engine jaw is of the proper design. It is important that the outermost point of the engine jaw is $1\frac{11}{16}$-in. back from the crankcase flange on which the starter mounts. There should be approximately $\frac{3}{32}$-in. clearance between the engine jaw and starter jaw when the latter is not meshing. This point is extremely important in all installations.

The engine jaw is usually splined, and mates with corresponding splines on the end of the crankshaft extension, or, in engines using an impeller, mates with splines on a countershaft geared to the crankshaft. In most cases, it is held in place longitudinally by means of a long screw extending

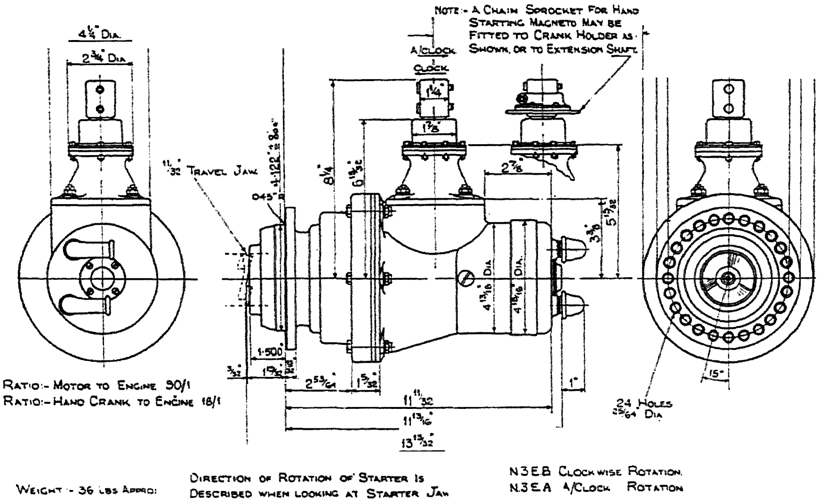

Fig. 2.—Installation diagram for Rotax Eclipse E160C starter

through to the crankshaft, to which it is threaded and locked by a heavy positive lock washer.

Hand Crank

Starters with the hand-cranking device should be so mounted as to bring the hand crankshaft through the right side of the fuselage (looking forward from the rear of the engine). The hand crank is then turned in a clockwise direction, with the operator facing the airscrew.

For engines equipped with supercharger blowers, in which the starter is applied to a geared shaft, it is then mounted on the engine so as to bring the hand crank through the left side of the fuselage (looking forward from the rear of the engine). The hand crank is then turned in a counter-clockwise direction, with the operator facing the airscrew.

The hand-crank assembly, which is furnished with each starter, consists of two parts : a crank handle and extension-shaft assembly. The extension-shaft assembly is designed to be permanently pinned to the starter cranking shaft, leaving the crank handle to be attached when its use is required (*see* Fig. 3).

The extension-shaft assembly is a thin wall, heat-treated steel tubing, reinforced at one end, and is tapered so that, after being pinned to the starter shaft, there is sufficient universal action to provide for any slight misalignment of the crank assembly.

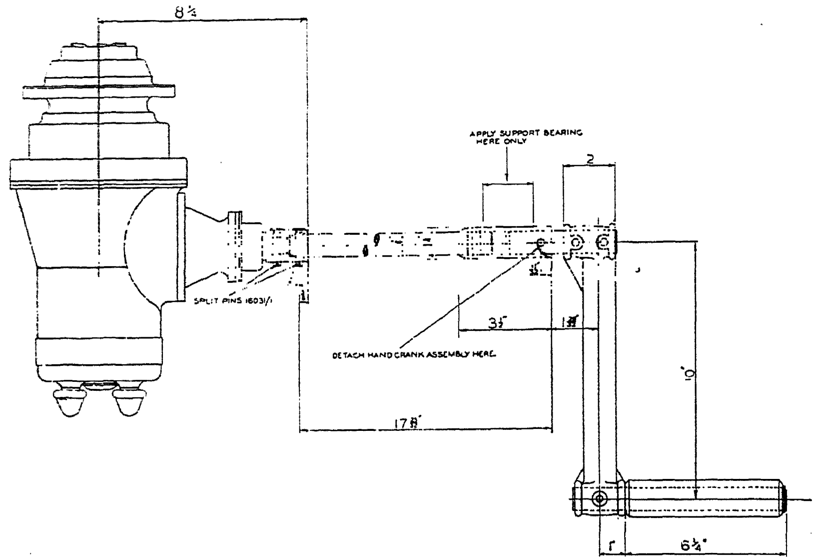

Fig. 3.—INSTALLATION DIAGRAM FOR HAND-CRANK ASSEMBLY

A $\frac{1}{4}$-in. diameter hardened pin is used to pin the extension-shaft assembly to the starter cranking shaft. The pin, which is held in place by a split pin, is purposely a loose fit in the extension assembly, so that the desired universal action can be obtained.

To the end of the extension assembly, opposite to that which is connected to the starter, is permanently attached a sleeve with spiral engaging slot, so that the hand crank is disengaged upon the starting of the engine.

Important

In all installations the bearing used to support the crank-extension shaft should be very rigidly mounted, and should be applied to the large-diameter sleeve at the cranking end. A ball bearing at this point, with provision for lubricating, is strongly recommended. Care should be taken that the extension shaft is properly aligned and turns without binding.

Wiring

In outboard-engine installations, or under conditions where it is necessary to locate the battery at a distance from the starter switch, the remote-control wiring circuit is desirable, both from the standpoint of

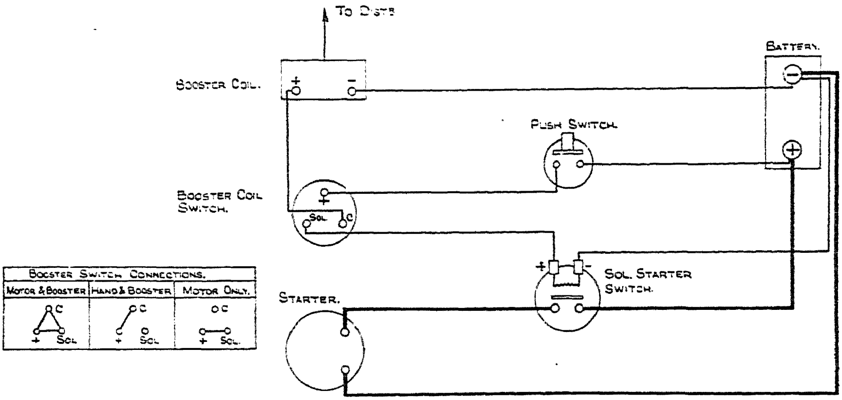

Fig. 4.—Wiring diagram for booster coil with hand or electric starter

weight saving, due to the elimination of excessively long heavy-duty cables, as well as for safety, due to the danger of transmitting heavy amperage through the aeroplane. The remote-control method employs a small lightweight panel-board switch, which excites a solenoid switch, which in turn closes the circuit between the battery and the starter (*see* Fig. 4).

Fig. 4 shows the use of a booster coil. The electrical operation of this unit is automatic. The energising of the booster coil is effected upon the engaging of the starter switch. The booster coil can be mounted on the starter or in any place conveniently located to the units with which it works in conjunction.

A good standard grade of heavily insulated stranded-copper wire should be used for all circuits. Care should be taken that all terminal lugs be soldered to the wiring cables, and the lugs protected with rubber nipples at their connection with the units. The length of wiring circuits should be kept as short as possible, both as a saving in weight as well as to minimise the voltage drop.

Cable as Indicated in Fig. 4	12 *v. Total Length in Each Circuit*			24 *v. Total Length in Each Circuit*	
	Below 20 *ft.*	20 *ft. to* 40 *ft.*	*Above* 40 *ft.*	*Below* 30 *ft.*	*Above* 30 *ft.*
Heavy Starter Cable . (▬▬▬)	B.E.S.A. Uniproof 64	248/·018	416/·018	B.E.S.A. Uniproof 64	248/·018
Light Solenoid Cable (———)	B.E.S.A. Uniflex 7	B.E.S.A. Uniflex 7	B.E.S.A. Uniflex 7	B.E.S.A. Uniflex 7	B.E.S.A. Uniflex 7

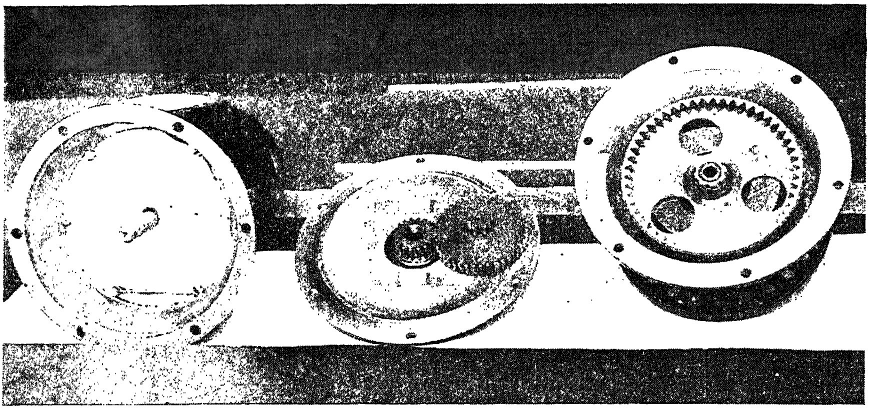

Fig. 5.—Sub-assembly of Rotax Eclipse E160 starter

We are indebted to British Airways, Ltd., for facilities for staging the illustrations shown in Figs. 5–14, illustrating the American type E160 starter.

Battery

A standard aeroplane type, non-spillable battery, 12 or 24 volts (depending on rated voltage of starter), should be used, many makes of which are now available. No specific recommendations can be made as to the size to be used, as this will depend on the current required by other aeroplane accessories used, such as landing and navigation lights, radio, etc.

The use of a generator for battery charging will provide a starting system to which little attention need be given, except a periodical inspection of the amount of distilled water in the battery. When no generator is used, a careful check must be made to keep the battery in a fully charged condition. It is under this condition only that good starting performance can be obtained.

Operation

For best results in starting, prepare engine in accordance with manufacturers' instructions, and operate starter electrically by pressing starter button, or manually by manipulating the hand crank. Engagement and release are entirely automatic and require no attention.

Should engine fail to start readily, the cause should be ascertained immediately to avoid running down the storage battery or to conserve human energy in hand cranking. If found necessary to unload priming charge from the cylinder, the airscrew should be pulled one-third to half of a revolution in its normal direction (switch off) so as to disengage the starter jaw. When released, the airscrew may be turned in an opposite direction as required, and the engine primed again for a new start. A

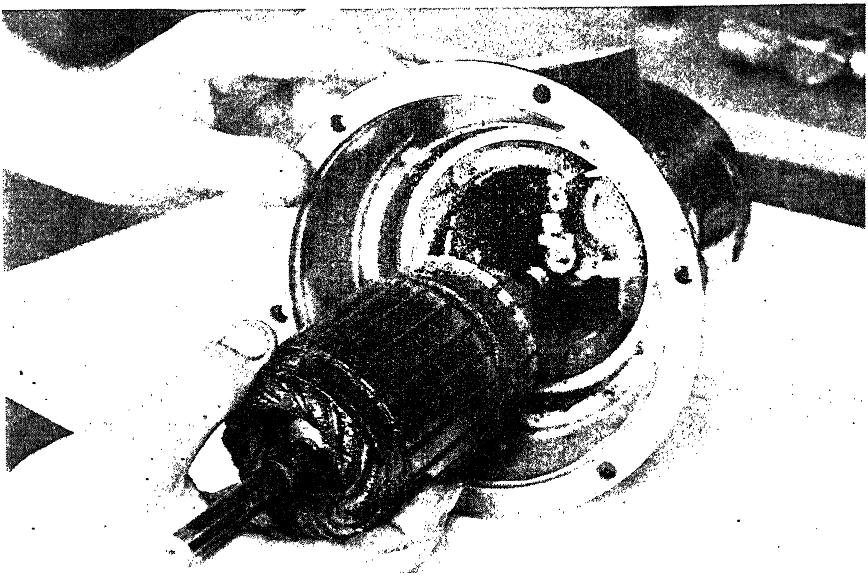

Fig. 6.—Withdrawing the armature of the E160 starter

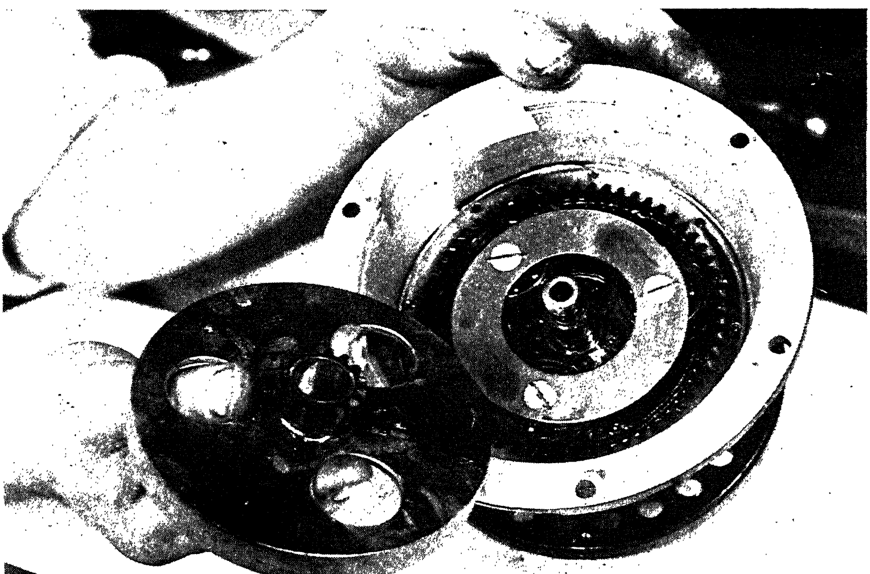

Fig. 7.—Withdrawing the Sun gear from its housing

"Watford booster coil" is a very desirable aid for starting under all conditions.

Dismantling

Reference should be made to Fig. 16, showing the electric motor and method of drive through the reduction and planetary gearing.

First take off the four nuts, which will remove the hand-crank attachment, then remove the six bolts, and the electric-motor assembly can be lifted off the front and intermediate housings, allowing drive pinion to remain intact.

The armature can be taken out of the motor assembly by successively removing window-strap cover, four brushes, bearing cap, armature nut, then proceed to the opposite end of the motor assembly and remove oil-seal plate. The armature can then be lifted out of this end. No further dismantling of the motor will be necessary unless other parts are worn or damaged and need replacement. The method of dismantling the balance of the parts of the motor may be easily determined by referring to Fig. 16.

By lifting the intermediate housing assembly off the front housing assembly, the intermediate gear shaft and remaining parts of the intermediate housing assembly can be removed in their respective order. The driving-barrel assembly can be taken out of the front housing assembly by successively removing the meshing-rod nut, starter jaw, and baffle-plate assembly, ball adjusting-nut locking ring, and ball adjusting nut. Care should be taken during dismantling not to lose any of the steel balls. They are held in place by a ball ring, and will be loose as soon as this part is removed.

The clutch-assembly setting will remain indefinitely. However, it is recommended that the torque value of the clutch be checked at the time of engine overhaul to ensure that it is kept in proper adjustment. A torque measuring device in the form of a prony brake is essential for this work.

The sun gear can be taken off the barrel assembly by removing the barrel nut, and the planetary pinions can be removed from the barrel assembly by taking out screws and rings. The annulus gear (or fixed internal gear) need not be removed from front housing unless damaged. If replacement is necessary, take out the studs holding this gear in place.

Assembly

By following, in an inverse manner, the instruction outlined under "Dismantling," assembly may be readily accomplished.

It will be found convenient, when assembling the driving barrel in the front housings, to coat the ballraces with grease to hold the balls in place. Sixty balls are required to each race.

It is not necessary to set the planetary pinions in any specific position when meshing them with the spur pinion and the fixed internal gear.

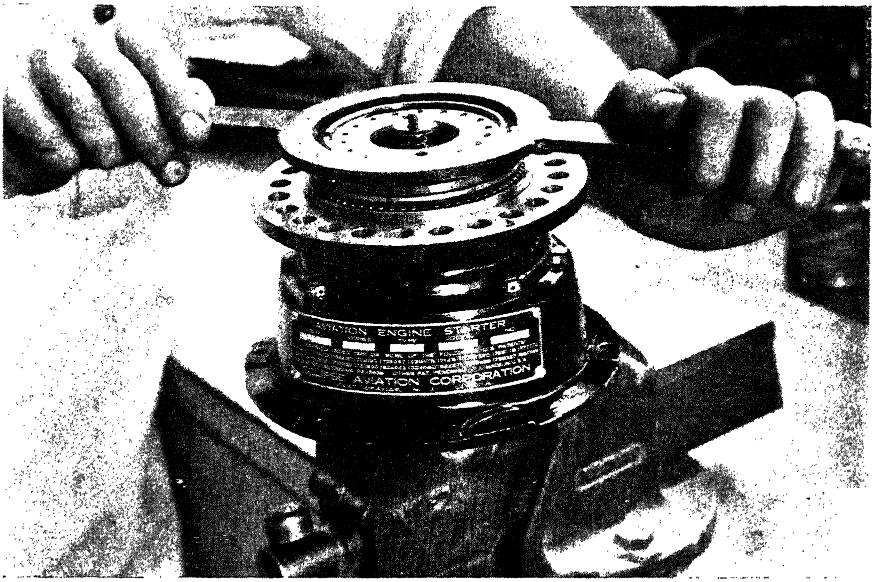

Fig. 8.—Removing ball race adjusting ring to release clutch assembly

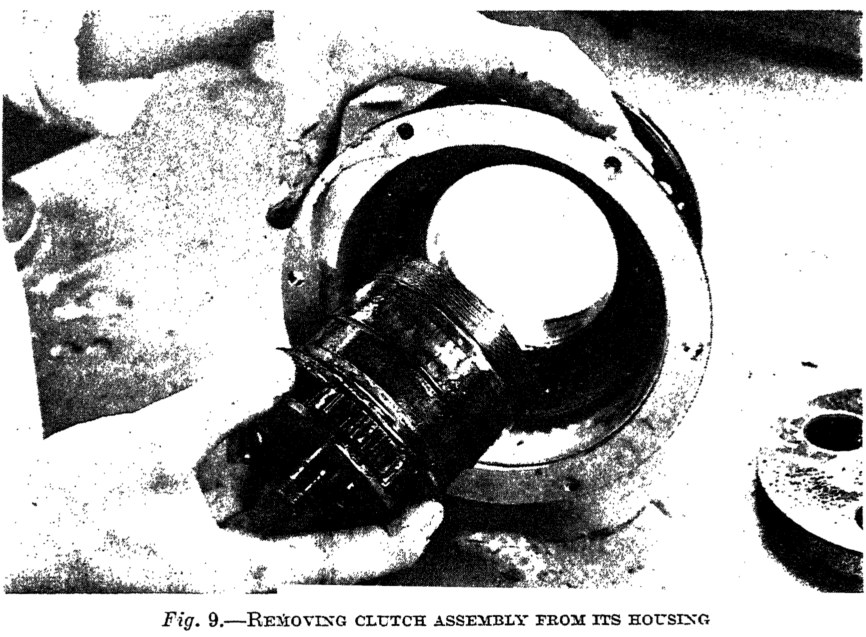

Fig. 9.—Removing clutch assembly from its housing

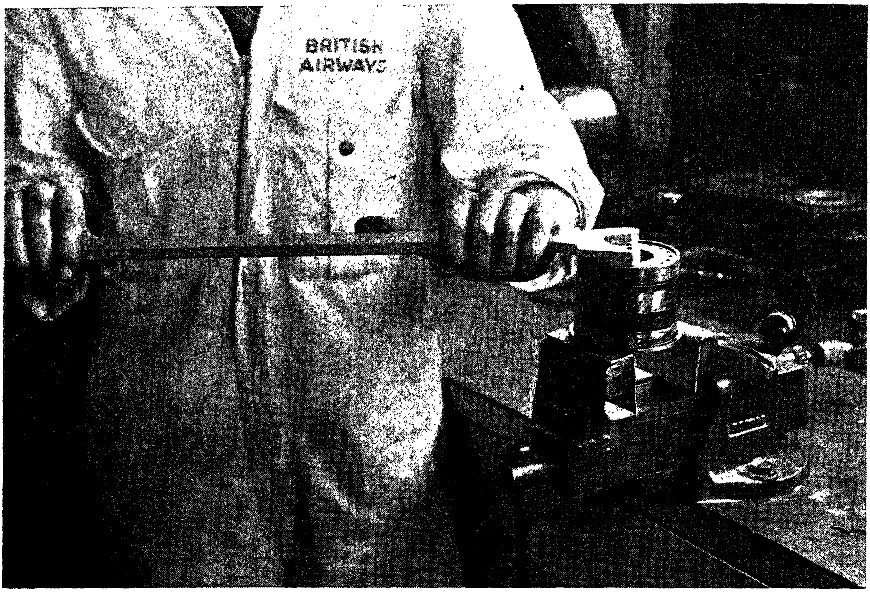

Fig. 10.—Removing clutch adjusting nut

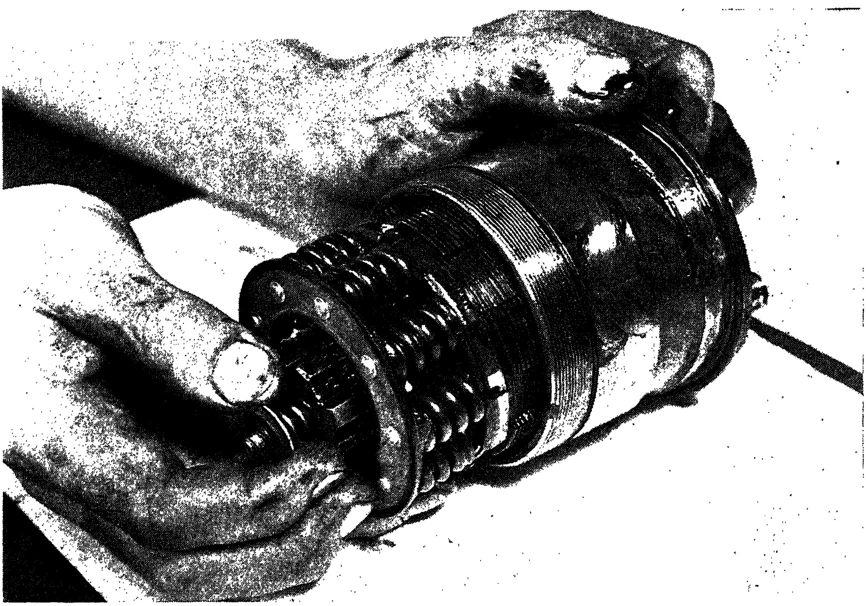

Fig. 11.—Removing clutch plates from barrel

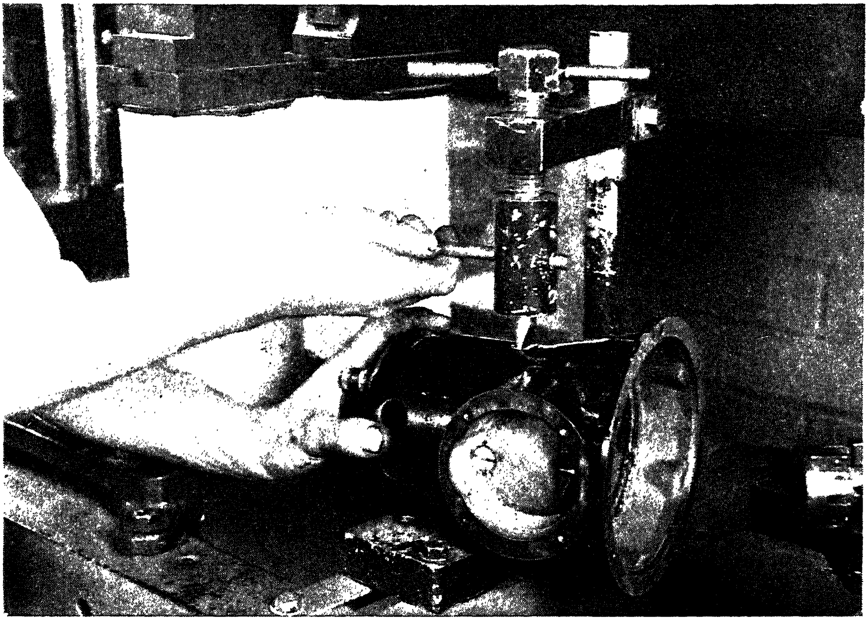

Fig. 12.—Removing pole shoe screws to enable field coils to be withdrawn

Care should be exercised that all screws, nuts, etc., are properly locked. The locking of certain screws in place with brass tie wire should not be overlooked.

CARE AND MAINTENANCE

It is recommended that the starter be given a careful inspection at least during every major "engine overhaul."

Do not lubricate between overhaul periods.

Should the starter be dismantled, it is very important that it be thoroughly cleaned before reassembling. Do not wash with petrol or attempt to clean the interior of the clutch-barrel assembly, as the discs which compose this part are specially lubricated with a graphite-base grease. The removal of this lubricant would seriously affect the operation of the unit.

LUBRICATION CHART

Part	*Lubricant*	*Manufactured by*
Ball bearings .	N.E. Grease	Edgar Vaughan & Co., Ltd., Birmingham
All gears .	Gredag	E. G. Acheson, Ltd., Thames House, Millbank, London, S.W.1
Plain bearings .	Grease	
Clutch discs .	No. 223	

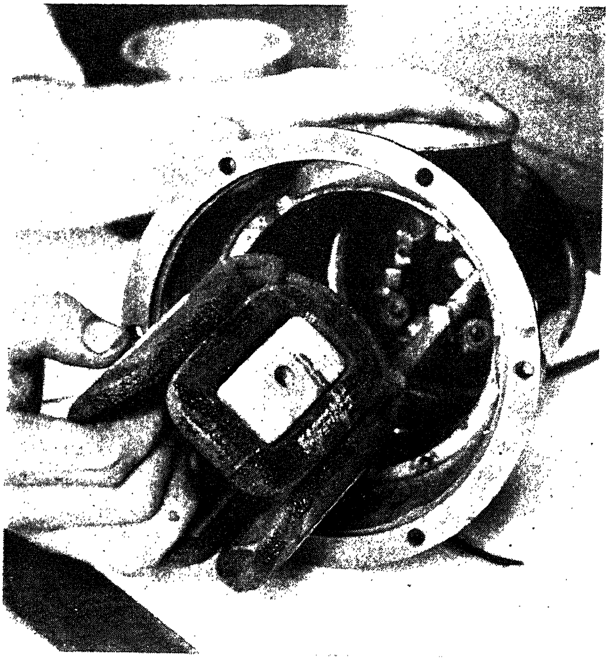

Fig. 13 (*left*).—REMOVING THE FIELD COILS

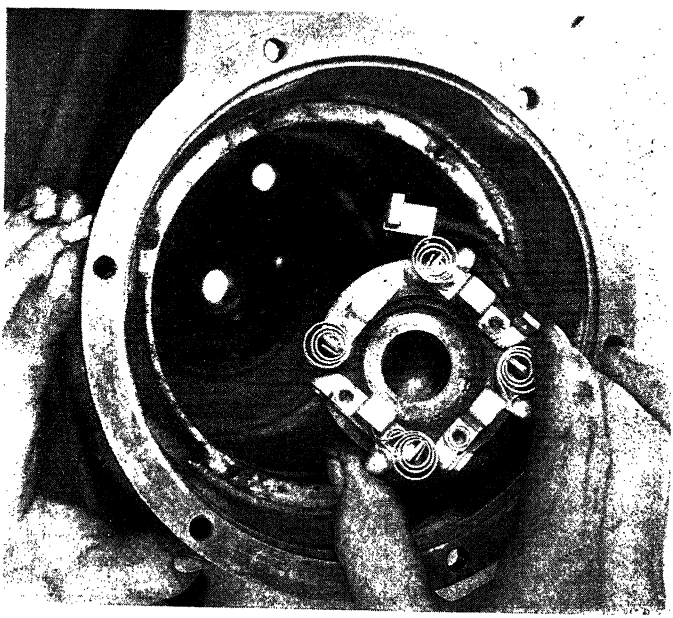

Fig. 14 (*right*).—REMOVING THE BRUSH GEAR

These lubricants can be obtained from Rotax Limited, London, N.W.10. It is very important that no other lubricants be used than those specified above. They have been decided upon after extensive test and research as the best for the purpose.

Brushes

The motor brushes should be inspected to see that they are bearing on the commutator, and that they do not bind in their respective holders. If examination should disclose " worn " brushes, they should be replaced immediately. Burning of commutator and insulation usually results from failure to make such a replacement in time.

Replacement brushes should be secured from the manufacturers, as they are of special material. If inferior brushes are substituted, satisfactory operation cannot be expected.

Brush Springs

The motor brush springs should be examined and tested at overhaul. The required tension is 18 oz. to 24 oz. If less than these figures, they should be replaced.

Commutator

The motor commutator should be kept free from oil and dirt. To clean the commutator, use a clean cloth moistened with petrol to remove any dirt, etc. ; only in case of a rough commutator should sandpaper (No. 000) be used, and in such cases the commutator should be given a final polish with No. 0000 sandpaper. (Do not use emery cloth or any other kind of material. Never put any lubricants, such as Vaseline or grease, on the commutator or brushes.) After cleaning, be sure that all of the sand or particles are blown out of the machine.

If the commutator has become pitted, the armature should be removed and a slight cut taken on a lathe across the face of the commutator. After this operation the commutator should be given a final polish with No. 0000 sandpaper.

Oil Seal

The filling of the gear housing and electric motor with excessive grease or oil may be caused by a worn seal assembly on the jaw. Replacement of the oil seal will eliminate this trouble.

Check during Major Overhauls

At major overhauls, a check should be made to ascertain that the starter jaw fully retracts when not cranking ; also, that the leather washer in the baffle-plate assembly is a tight fit around the starter jaw. It is important that this leather washer and also the washer between the starter jaw and the screw shaft be replaced if at all worn or damaged. If not

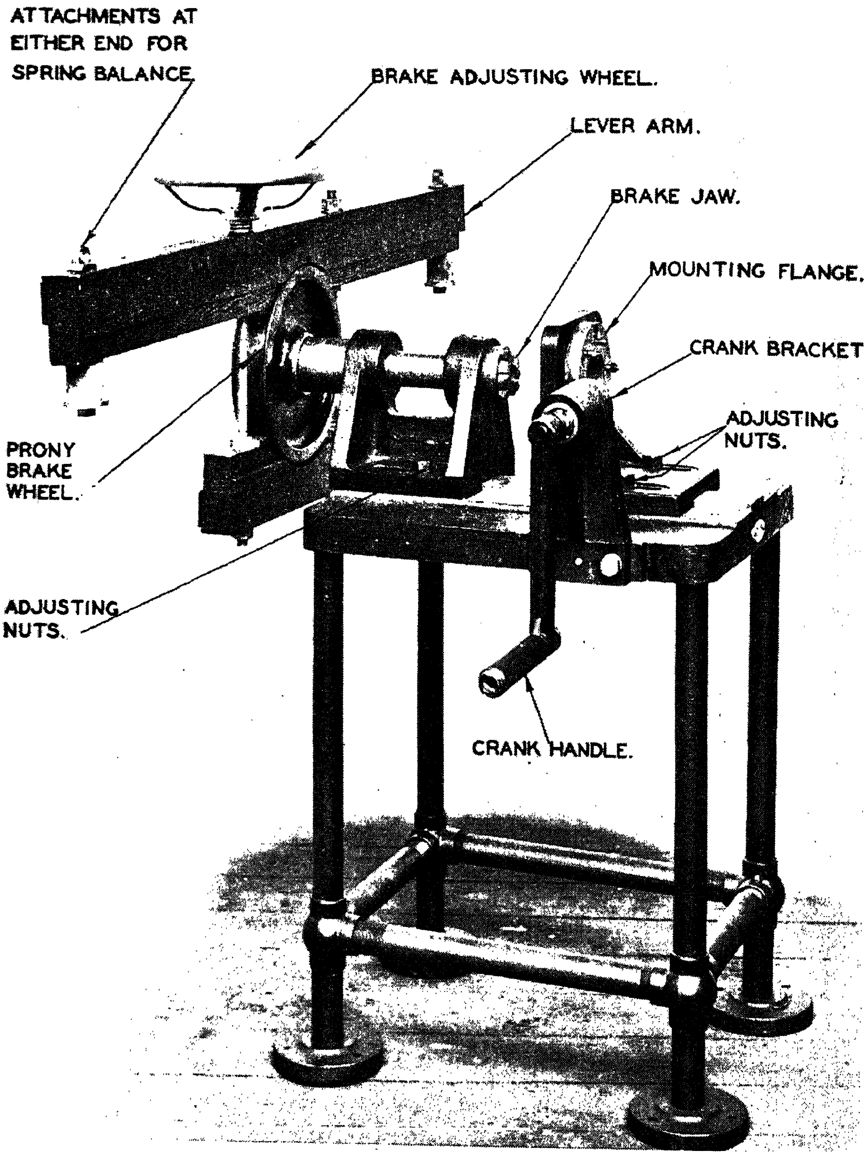

Fig. 15.—" PRONY " BRAKE FOR TESTING E160 STARTERS

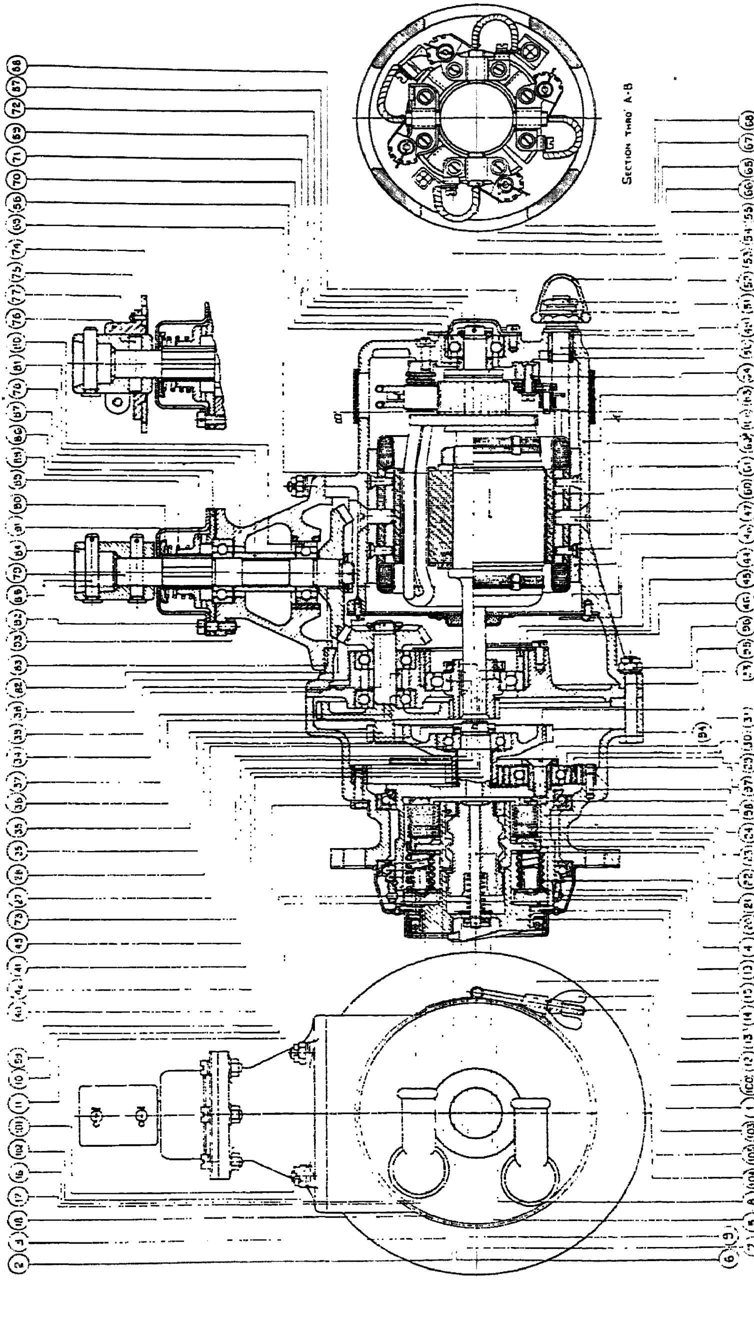

Fig. SECTIONAL NG OF E160C

replaced, oil will pass from the engine to the interior of the starter and its operation will be impaired.

Check the friction of the baffle-plate oil seal to ascertain if it has sufficient tension to hold the starter jaw in position so that the jaw will advance forward to mesh with the engine jaw. The jaw travel should be $\frac{11}{32}$ in. This can be checked from the innermost position of the starter jaw to the outermost advanced position where it begins to rotate. The jaw should be slightly tapped back to the innermost position before checking. Then apply rotation to either the hand crank or electric motor. The starter jaw will then advance forward without rotating until it has reached its outermost advanced position, and it will then begin to rotate. At this point the distance of travel should be checked from the innermost position.

If the bronze bearing in the sun gear should become oversize, it should be rebushed by the manufacturers.

TROUBLES AND REMEDIES

Before proceeding with an investigation of any trouble, first make sure all wiring connections are properly made and not loose or corroded. The top of the battery should be kept clean and the terminals covered with Vaseline in order to avoid corrosion.

Motor not Operating

To locate the cause of the motor not operating, or operating at a low speed, when switch is closed, proceed as follows :

(1) Check the battery to make sure it is not discharged. If the battery is found dead, the cause should be determined before a charged battery is installed.

(2) Remove window strap covering the brush windows, and make sure that all brushes are bearing on the commutator and that the brushes do not bind in their respective holders, but are free to move. Replace all worn brushes.

(3) Examine commutator and remove any accumulation of dirt or grease.

(4) Connect a jumper cable across the large terminals of the solenoid switch. If the motor then operates, the solenoid or starting switch is the cause of the trouble.

If the motor operates but does not turn engine, the starter should be removed from engine and the jaw and friction ring examined. A collection of oil between jaw and oil seal leather will sometimes prevent the jaw from advancing, and should be cleaned out.

Clutch Setting

Extensive experience has indicated that the original clutch setting will remain constant indefinitely.

Special torque measuring equipment is required properly to set the clutch. Without such equipment, the clutch cannot be accurately reset and no adjustment should be attempted.

Clutch Adjusting and Test

Test stand equipment : a prony brake-test stand and scale is recommended for clutch testing (*see* Fig. 15).

Caution.—Care should be taken, when adjusting the clutch, gradually to attain the required setting without overheating.

(1) If clutch discs have not been removed or adjustment disturbed during overhaul, the clutch setting can be checked as follows :

Mount starter on clutch stand with baffle plate removed. Adjust mounting bracket so that the clearance between starter jaw and test-stand adjusting-sleeve jaw equals $\frac{3}{32}$ in. Removal of the baffle plate necessitates manual engagement of the starter jaw with test-stand jaw. Lock the brake drum and operate the starter for a period of 5 seconds. Repeat the above procedure five times at 1-minute intervals.

If the torque reading on the scale remains constant at 550 lb./ft. within plus or minus 20 lb./ft., it can be considered satisfactory.

Key to Fig. 16.

1. Starter jaw ; 2. Screw shaft ; 3. Screw shaft nut ; 4. Spline nut ; 5. Mesh spring ; 6. Oil seal washer ; 7. Oil seal washer (leather) ; 8. Mesh rod ; 9. Mesh rod nut ; 10. Clutch adjusting nut ; 11. Circlip for item 10 ; 12. Ball ring adjusting nut ; 13. Ball ring adjusting nut lock ring ; 14. Spring plate assembly ; 15. Clutch spring ; 16. Ball ring ; 17. Balls for bearing ; 18. Ball race ; 19. Spring spacer ; 20. Spline nut bushing ; 21. Clutch disc, outer ; 22. Clutch disc, inner ; 23. Barrel complete with studs ; 24. Clutch spacer ; 25. Sun gear assembly ; 27. Ball bearing ; 28. Barrel nut ; 29. Planet pinion ; 30. Planet ball bearing ; 31. Planetary ring ; 33. Planetary screw ; 34. Intermediate housing (with bearing bushes) ; 35. Intermediate gear ; 36. Ball bearing ; 37. Ball bearing spacer (for driving pinion bearing) ; 38. Driven bevel gear ; 39. Driven bevel gear nut ; 40. Driving pinion ; 41. Driving pinion nut ; 42. Lock tab ; 43. Ball bearing ; 44. Ball bearing spacer (for internal gear wheel bearing) ; 45. Ball bearing retainer (for internal gear wheel bearing) ; 46. Screw for item 45 ; 47. Oil seal assembly ; 48. Fixing screw for item 47 ; 49. Armature post ; 50. Post insulator ; 51. Post insulator bush ; 52. Insulating washer for item 50 ; 53. Terminal lug ; 54. Terminal nut ; 55. Terminal cover ; 56. Screw for brush gear ; 57. Bearing cap ; 58. Bearing cap screw ; 59. Ball bearing ; 60. Yoke ; 61. Screw for yoke and pole shoe ; 62. Pole shoe screw ; 63. Motor housing ; 64. Brush gear unit complete ; 65. Brush, flex and tag ; 66. Terminal screw ; 67. Brush trigger ; 68. Brush trigger spring ; 69. Armature 12 v. C/W or A/C, Armature 24 v. A/C, Armature 24 v. C/W ; 70. Armature spacer ; 71. Armature spacer ; 72. Armature nut ; 73. Armature key ; 74. Chain sprocket ; 75. Chain sprocket rivet ; 76. Chain sprocket boss ; 77. Crank pin ; 78. Hand crank housing (with bearing bush) ; 79. Hand crank shaft ; 80. Ball bearing ; 81. Ball bearing spacer ; 82. Driving bevel gear ; 83. Driving bevel gear nut ; 84. Crank holder ; 85. Crank pin ; 86. Ratchet, stationary (clock) ; ratchet, stationary (anti-clock) ; 87. Endshake washer for bearing ; 88. Ratchet, movable (clock) ; ratchet, movable (anti-clock) ; 89. Ratchet spring ; 90. Ratchet spring plate ; 91. Ratchet cover ; 92. Ratchet cover screw ; 93. Ratchet cover screw nut ; 94. Front housing ; 95. Fixing bolts for front housing ; 96. Nut for item 95 ; 97. Annulus gear ; 98. Dowel pin ; 99. Screw for item 97 ; 100. Baffle plate complete with oil seal and fixing screw ; 101. Stud for item 78 ; 102. Nut for item 101 ; 103. Window strap complete with wing nut and bolt ; 104. Tee bolt for item 103 ; 105. Wing nut for item 103 ; 106. Pole shoe assembly.

WEAR CHART FOR ROTAX-ECLIPSE E160C STARTER

Ref. on Fig. 17	*Part and Description*	*Dimensions New*	*Permissible Worn Dimensions*	*Clearance New*	*Permissible Clearance between any Two Worn Parts*	*Remarks*
1	*Driving Barrel and Clutch* Ballrace (inner ring), Hoffmann 1786	—	—	—	—	Bearing face to be free from pit marks.
2	*Barrel and Sun Gear* Stem diameter . .	0·687″–0·6865″	0·6845″	0·0005″–	0·0035″	—
	Bore of bush . .	0·68885″–0·6875″	0·690″	0·00175″		
3	Clutch plates . .	—	—	—	—	Plates to be free from pick-up and serious score marks.
4	Clutch springs } Free length .	$\frac{7}{8}$″				Set of 9 springs for each starter must register within 5 lb. of each other.
	Load when comp. to $\frac{15}{32}$″	160–200 lb.	145 lb.	—	—	
5	*Driving barrel (Salvage)* Stage of re-machining C/bore: 1st	0·475″–0·476″	—	—	—	To suit stud 16474 A 0·4773″ + 0″ − 0·0004″ dia.
	Stage of re-machining C/bore: 2nd	0·480″–0·481″	—	—	—	To suit stud 16474 B 0·4823″ + 0″ − 0·0004″ dia.
	Stage of re-machining C/bore: 3rd	0·485″–0·486″	—	—	—	To suit stud 16474 C 0·4873″ + 0″ − 0·0004″ dia.
	Stage of re-machining C/bore: 4th	0·490″–0·491″	—	—	—	To suit stud 16474 D 0·4923″ + 0″ − 0·0004″ dia.
6	Spline nut bushing Thickness between thrust faces	0·122″–0·131″	0·117″	—	—	—
7	Planet pinion Ballrace housing diameter	1·2591″–1·2594″	—	—	—	—
8	*Front Housing* Ballrace housing diameter, Hoffmann 1787	4·0425″–4 044″	—	—	—	—
9	Ballrace (outer ring)	—	—	—	—	To be free from pit marks.
10	Balls . . .	—	—	—	—	To be free from pit marks.
11	*Intermediate Housing* Ballrace housing diameter	1·2590″–1·2593″	—	—	—	—
12	*Crank Housing* Ballrace housing diameter	1·377″–1·3775″	—	—	—	—
13	Spring for ratchet—free length . .	$1\frac{1}{4}$″	—	—	—	Free length must not be less than 1″.
14	*Screw Shaft* Spline nut assembly Thickness of flange .	0·153″–0·159″	0·146″	—	—	—
15	Meshing spring—free length . . .	1″	—	—	—	Free length must not be less than $\frac{15}{16}$″.
16	*Brush Gear* Brush (length) . .	0·750″	0·500″	—	—	—
17	*Armature* Commutator diameter	1·500″–1·510″	1·375″	—	—	—

Maximum side play on ballraces, 0·006 in.

Replace gears when faces of teeth become worn sufficiently to obliterate original involute curvature.

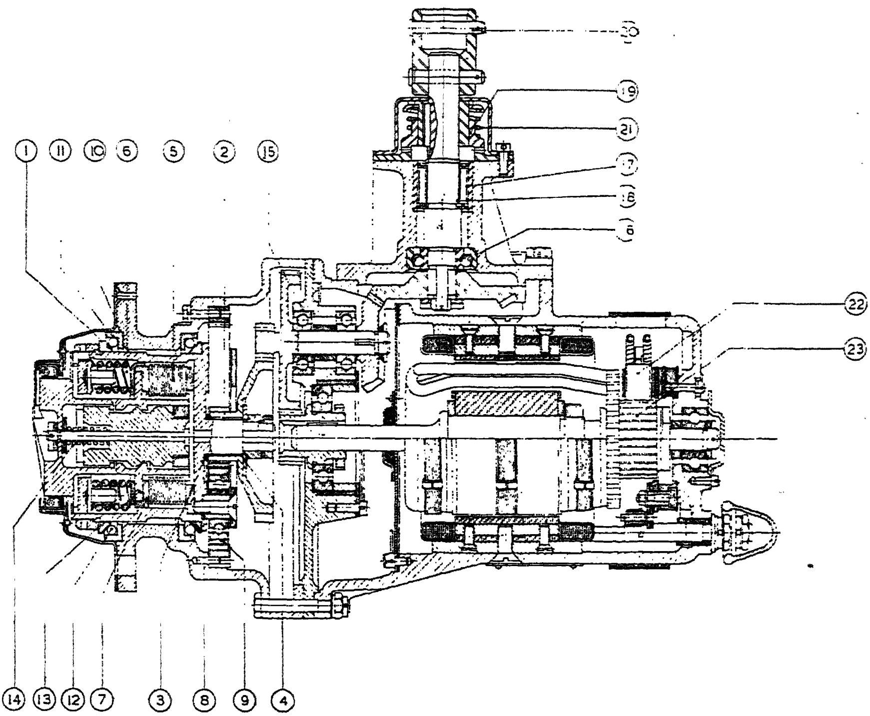

Fig. 17.—Wear chart diagram for Rotax E160C starter

To lower the setting, screw the clutch-adjusting nut outwards; to raise, screw inwards. After the correct setting has been found, allow starter to cool to room temperature, and operate starter five consecutive times to determine if setting remains constant.

(2) If clutch discs have been removed or adjustment altered, the clutch setting must be approached gradually, starting with approximately 200 lb./ft. setting. Operate starter for periods of 5 seconds, with 1-minute intervals, until the clutch maintains a constant torque value. Then gradually increase clutch value, operating starter between each increase in clutch setting until the required setting is obtained. When final setting is reached, allow starter to cool to room temperature, and give five consecutive engagements of 5 seconds' duration at 1-minute intervals. If setting remains constant, the clutch has been properly adjusted.

(3) When adjusting and testing the clutch following replacement of clutch discs, the same procedure as used above in (2) should be followed. However, the number of tests should be raised to twenty at minute

WEAR CHART FOR ROTAX-ECLIPSE STARTER TYPE E160R.

Ref. on Fig. 18	*Part and Description*	*Dimensions New*	*Permissible Worn Dimensions*	*Clearance New*	*Permissible Clearance between any Two Worn Parts*	*Remarks*
1	*Driving Barrel and Clutch* Ballrace (inner ring) .	—	—	—	—	Bearing face to be free from pit marks.
2	*Barrel and Sun Gear* Stem diameter .	0·687–0·6865″	0·6845″–	0·0005″–	0·0035″	—
	Bore of bush . .	0·688″–0·6875″	0·690″	0·0015″	—	—
3	Sun gear thrust washer (small) Thickness . .	0·060″–0·064″	0·030″	—	—	—
4	Sun gear thrust washer (large) Thickness . .	0·062″–0·066″	0·030″	—	—	—
5	Clutch plates . .	—	—	—	—	Plates to be free from pick-up and serious score marks.
6	Clutch springs Free length .	$\frac{7}{8}$″				
	Clutch springs Load when comp. to $\frac{13}{16}$″ .	160–200 lb.	145 lb.	—	—	Set of 9 springs for each starter must register within 5 lb. of each other.
7	Spline nut bushing Thickness between thrust faces . . .	0·122″–0·131″	0·117″	—	—	—
8	Driving barrel (salvage) Stage of re-machining C/bore: 1st	0·475″–0·476″	—	—	—	To suit stud 16474 A 0·4773″ + 0″ − 0·0004″dia.
	Stage of re-machining C/bore: 2nd	0·480″–0·481″	—	—	—	To suit stud 16474 B 0·4823″ + 0″ − 0·0004″dia.
	Stage of re-machining C/bore: 3rd	0·485″–0·486″	—	—	—	To suit stud 16474 C 0·4873″ + 0″ − 0·0004″dia.
	Stage of re-machining C/bore: 4th	0·490″–0·491″	—	—	—	To suit stud 16474 D 0·4923″ + 0″ − 0·0004″dia.
9	Planet pinion Ballrace housing diameter	1·2598″	—	—	—	Close fit to suit ballrace.
	Front Housing					
10	Ballrace housing diameter	4·043″–4·046″	—	—	—	—
11	Ballrace (outer ring) .	—	—	—	—	Bearing face to be free from pit marks.
12	Balls	—	—	—	—	To be free from pit marks.
	Screw Shaft					
13	Spline nut assembly Thickness of flange .	0·153″–0·159″	0·146″	—	—	—
14	Meshing spring—free length	1″	—	—	—	Free length not to be less than $\frac{15}{16}$″.
	Intermediate Housing					
15	Ballrace housing diameter	1·2598″	—	—	—	Close fit to suit ballrace.
	Crank Housing					
16	Ballrace housing diameter	1·3780″–1·3783″	—	—	—	Close fit to suit ballrace.
17	Roller-race (inside diameter)	1·000″–1·001″	1·005″	—	—	—
18	Crankshaft (diameter for roller-race)	0·6240″–0·6245″	0·6202″	—	—	—
	Movable Ratchet on Spline Collar					
19	Collar, spline diameter .	0·999″–1·000″	0·990″	0·003″–	0·015″	—
	Ratchet, spline diameter	1·003″–1·005″	1·014″	0·006″	—	—
20	Crank bolt . . .		—	—	—	Replace when worn or offset $\frac{1}{32}$″.
21	Ratchet spring — free length	$1\frac{1}{4}$″	—	—	—	Free length must not be less than 1″.
	Brush Gear					
22	Brush (length) . .	0·750″	0·500″	—	—	—
	Armature					
23	Commutator diameter .	1·500″	1·375″	—	—	—

Maximum side play on ballraces, 0·006 in.

Replace gears when faces of teeth become worn sufficiently to obliterate original involute curvature.

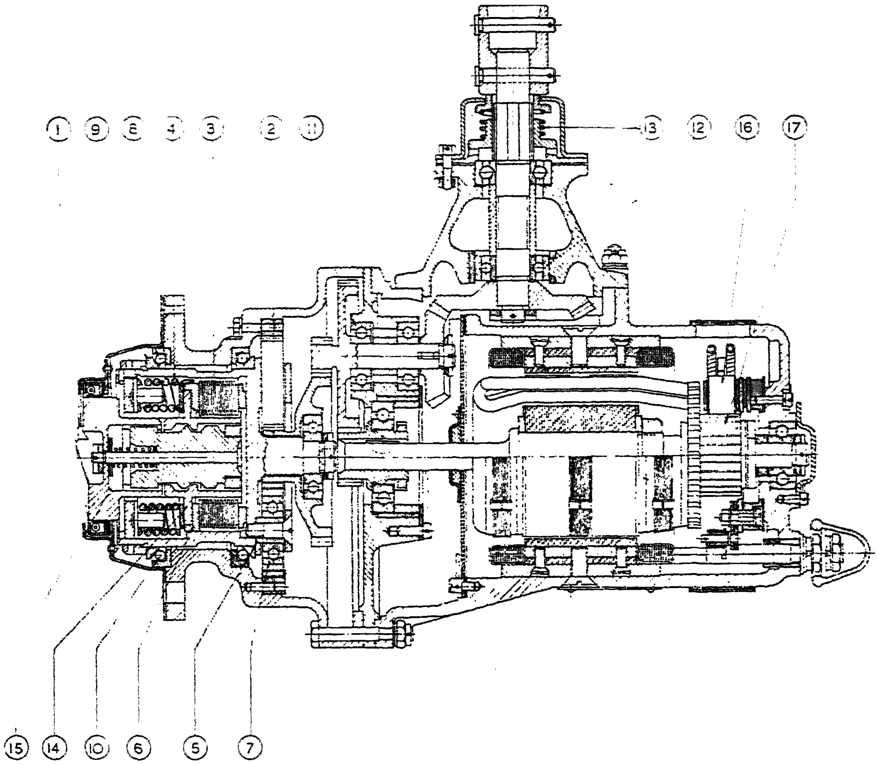

Fig. 18.—Wear chart diagram for Rotax-Eclipse E160R starter

intervals, in order to run in new clutch discs to the point of maintaining a constant torque value.

The general procedure in clutch adjusting and testing should be gradually to attain the required setting without overheating. In cases where the discs have been used and broken in, the attainment of the final setting can be more rapid. It is very important that no other grease excepting that specified under "Lubrication" be used. The lubricant has been selected as the result of exhaustive tests, and its use is necessary to successful operation.

ROTAX-ECLIPSE TYPE N3EM AND Y150B STARTERS

THE types N3EM and Y150B direct cranking electric starters are designed to crank an engine continuously with the power available from a standard aeroplane accumulator. They consist of an electric motor which drives reduction gearing of 122 : 1 (Y150B, 40 : 1) operating an automatic meshing and demeshing mechanism from an adjustable torque overload release.

The N3EM type is provided with hand-turning gear (ratio of hand crank to jaw 18 : 1), to provide a means of turning over the engine in cases of emergency, such as may be caused by some fault in the electrical system.

Referring to the cross sections (Figs. 5 and 7), it will be seen that a pinion, mounted on the electric motor armature shaft, drives the crown gear. This is integral with a spur pinion which meshes with three planetary gears. These are mounted on the second sun gear and run in a stationary gear fastened to the housing. This planetary system in turn drives another planetary system which drives the barrel containing the torque overload release—a spring-adjusted, multiple-disc clutch. The externally splined clutch discs are driven by the barrel, and the internally splined discs drive the spline nut.

Threaded within this is a screw shaft which is caused to advance at the first rotation until the stopnut rests against the back end of the threads. The starter jaw advances with the screw shaft and meshes with the engine jaw.

A friction brake is used to make the jaw advance into mesh before rotating. This consists of a three-piece friction ring, having tips which fit into corresponding slots in the jaw. It is held in place on the barrel plate by a spring of predetermined tension.

The rear faces of the starter jaw teeth are sloped so that when the engine starts the jaw is put out of mesh. The clutch has a safety device to allow only the desired amount of torque to be used when turning the engine over, and also to protect the starter from all possible damage in case of engine backfires.

The hand-turning extension as on type N3EM can be fixed at any 30° angle between the lines A–B–A (*see* Fig. 3).

INSTALLATION

Engine

These starters are applicable to engines having the standard 5-in. S.A.E. starter mounting flange. Six studs are located in this flange on a 4-in. bolt circle.

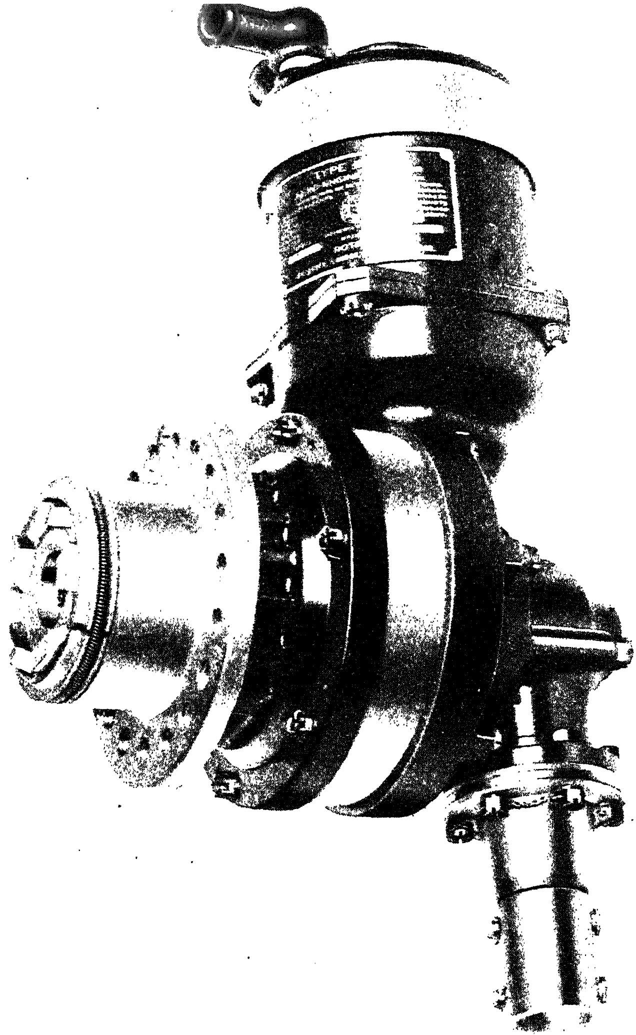

Fig. 1.—Rotax-Eclipse type N3EM direct cranking starter

Examine the engine jaw, ascertain if the jaw is a proper one, and make sure that it mates with the jaw on the starter. There should be approximately a $\frac{3}{32}$-in. clearance between the engine jaw and the starter jaw when the latter is out of mesh. This should also be checked when making

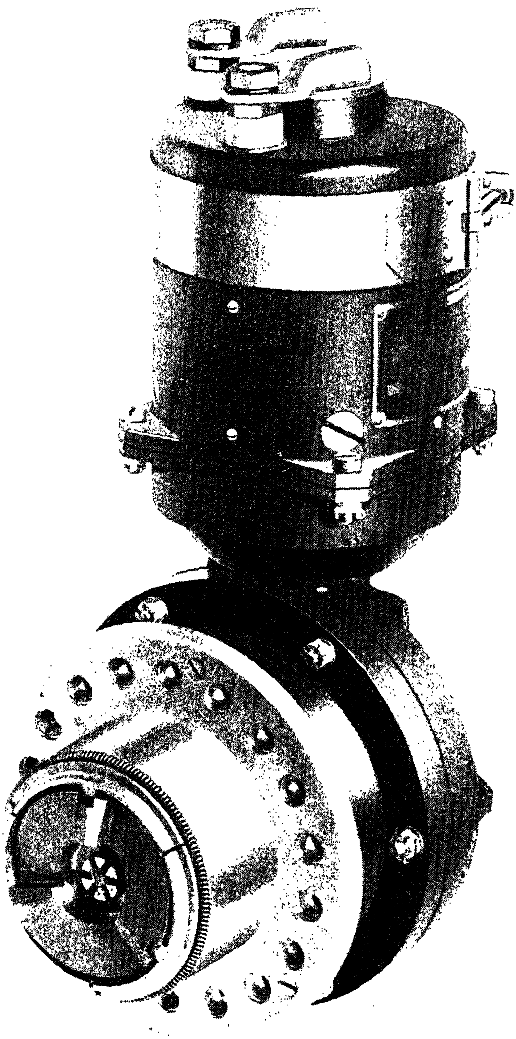

Fig. 2.—Rotax-Eclipse type Y150 direct cranking starter

the installation. If the engine is not fitted with a 5-tooth jaw (3-tooth jaw in the case of Y150B starters), it is necessary to obtain the correct jaw and the attaching parts before attempting to install the starter.

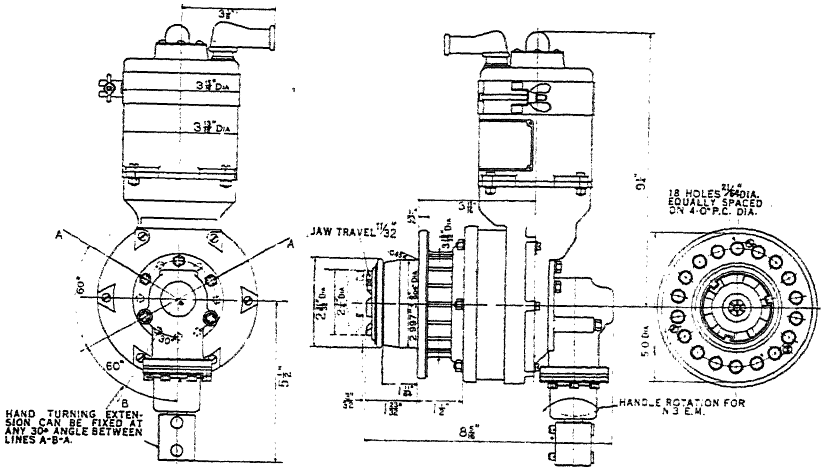

Fig. 3.—Installation diagram for Rotax-Eclipse type N3EM starter

Starter

The flange on the starter (Fig. 3) is drilled with 18 holes, providing various positions, 20° apart, in which the starter can be mounted to give the best clearance. The starter will operate equally well in any position.

Battery

The N3EM starter should be operated from a 12- or 24-volt battery of adequate capacity and the Y150B starter from a 12-volt battery. The

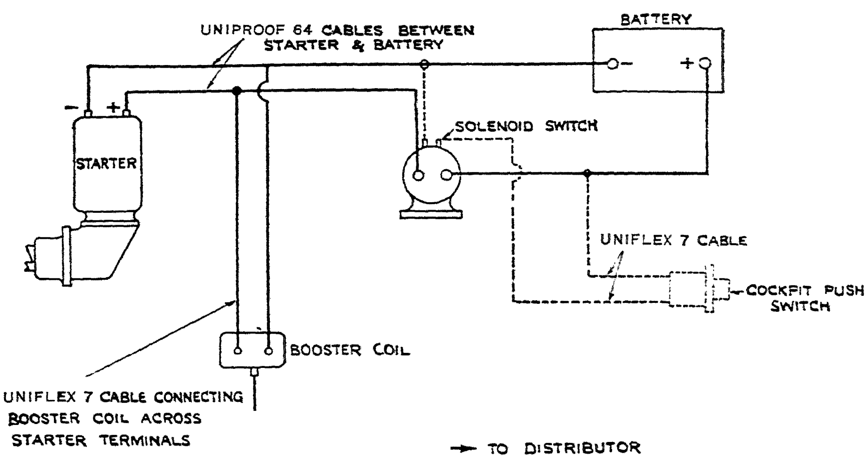

Fig. 4.—Connection diagram for using booster coil in conjunction with direct cranking starter

regular aeroplane type non-spillable battery should be used. The size of the battery depends upon the current required in addition to the starter, on landing lights, navigation and instrument lights, radio, etc. For single- or twin-engine use it is recommended that at any rate the capacity be not less than 25 ampere-hour, it being assumed that there is a charging generator on the aeroplane. For four-engine aeroplanes, and in all cases where a charging generator is not fitted, a battery of at least 40 ampere-hour capacity should be employed. Suitable batteries are the Air Ministry Type " B " accumulators, 12-volt, 25 ampere-hour, and 12-volt 40 ampere-hour, the respective weights of which are 30 lb. and 42 lb.

It is desirable to install the battery as close to the starter as possible to simplify the wiring.

Wiring

The use of a solenoid switch is recommended where the starter is at some distance from the push switch. In this type of installation an ordinary push button in the cockpit is sufficient for the current which it is required to carry. The wiring will consist of two circuits, the " battery-starter-solenoid " circuit and the " solenoid-push-switch-battery " circuit, as shown in the wiring diagram (Fig. 4).

The wire used in the main circuit should be Uniproof 64 stranded copper cable, heavily insulated. All terminals should be completely covered with insulators to prevent short circuits. Uniflex 7 cable is recommended for use in the push-button circuit.

Booster Coils

The coil is connected in parallel across the starter by means of the two cable clamps located in the two holes under the unsealed cover, via the two small unions. This method of connection brings the coil into action immediately the starter button is pressed. As soon as the engine picks up, the main magnetos provide the ignition. The H.T. lead from the large union on the booster coil is connected to the small hand magneto union on the magneto distributor screen, from whence it is led via the distributor to the engine.

No attempt should be made to reset the coils. For this reason the adjusting-screw cover is sealed.

Should it be found absolutely necessary to reset the coil, this can be done by first breaking the seal, slacking off the locknut, and swivelling the cover to one side. This gives access to the adjusting screw. If now an ammeter is connected in series with the coil and 12 volts applied to the primary winding, the points can be adjusted so that the current consumption of the coil is 1·6 to 1·8 amps. At this setting there should be regular sparking across a 9-kilovolt standard gap when distributed to same via a magneto rotating at 60 r.p.m.

Should the points require cleaning, this may be done by first removing

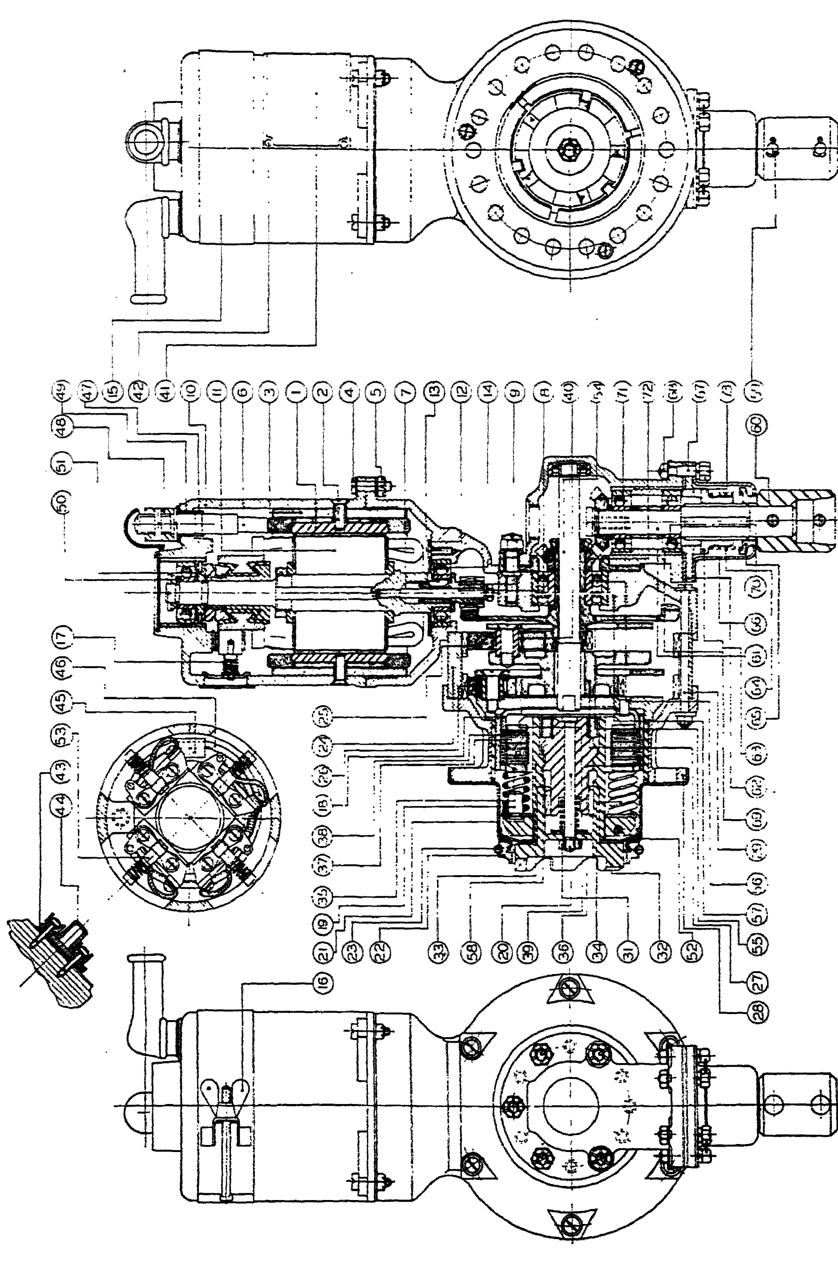

Fig. 5.—SECTIONAL DRAWING OF ROTAX-ECLIPSE N3EM STARTER

the base plate—held by four small screws and clamp plates—when access may be obtained to the points. Great care must be taken not to bend or distort the tremblers. Only fine carborundum cloth and benzine should be used for cleaning, and particles of dust must not be left on coil or contact.

Caution.—When testing coils, ensure that an adequate earth return is provided from the magneto. The cable screening should not be relied upon for this purpose, but should be paralleled by a suitable cable.

Operation

The engine manufacturer's instruction book should first be followed for preparation of the engine before commencing operation.

Usually the spark is at full advance and the throttle open when the starter is operated. If the engine fails to start readily, the cause should be ascertained at once in order to avoid running the battery down. If it is required to unload the cylinders off their charge, the propeller should be pulled through one-third or half a turn in its normal direction (switch off) to disengage the starter jaw. When released, the propeller may be turned to the opposite direction, as required, and then primed again for a new start.

The use of a hand-starter magneto or booster coil will facilitate starting, especially in cold weather. The latter is preferable, as a battery will be available in the aeroplane. The wiring diagram (Fig. 4) shows the connections if the Rotax booster coil is used.

Care and Maintenance

Do not put oil on the commutator, as it will seriously hinder the operation of, or cause considerable damage to, the motor.

Key to Fig. 5

1. Pole shoe assembly; 2. Pole screw; 3. Yoke; 4. Motor housing screw; 5. Motor housing nut; 6. Field coil assembly; 7. Woodruff key; 8. Retaining bolt; 9. Driving pinion; 10. Motor housing; 11. Armature assembly; 12. Bearing retainer; 13. Flathead steel screw; 14. Ball bearing (Hoffmann); 15. Window strap assembly; 16. Wing nut; 17. Brush spring assembly; 18. Barrel and plate assembly; 19. Spring ring assembly; 20. Operating rod; 21. Baffle plate; 22. Friction ring; 23. Friction spring; 24. Annulus gear assembly; 25. Planet pinion assembly; 26. 2nd planet pinion assembly; 27. Intermediate gear assembly; 28. Front housing; 29. Housing screw; 31. Operating rod nut; 32. Starter jaw; 33. Spline nut; 34. Clutch spring; 35. Spring spacer; 36. Barrel snap ring; 37. Outer clutch disc; 38. Inner clutch disc; 39. Backing washer; 40. Planetary bearing; 41. Name plate; 42. Parker drive screws; 43. Brush rest assembly; 44. Brush box; 45. Terminal post (Neg.); 46. Jumper wire (Neg.); 47. Field post insulator; 48. Field post nut; 49. Bush; 50. Ball bearing (Hoffmann); 51. Bearing spacer; 52. Oil seal assembly; 53. Brush assembly; 54. Crown gear shaft; 55. Crown gear; 56. Double row ball bearing (Hoffmann); 57. Rear housing; 58. Screw shaft; 59. Crank pin; 60. Crank holder; 61. Hand crank shaft; 62. Ratchet, stationary; 63. Ratchet, movable; 64. Ratchet spring; 65. Ratchet spring plate; 66. Ratchet cover; 67. Ratchet cover screw; 68. Ratchet cover nut; 69. Hand crank housing; 70. Ball bearings (Hoffmann); 71. Bevel wheel (driving); 72. Bevel wheel (driven); 73. Bearing spacer.

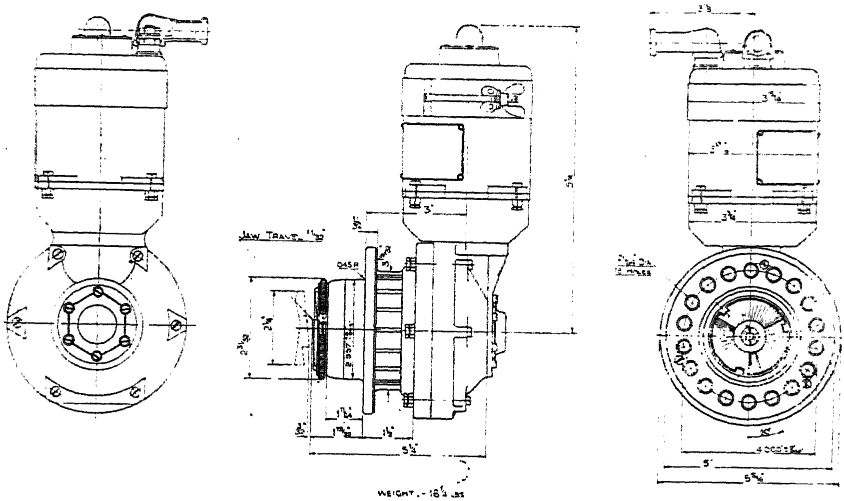

Fig. 6.—Installation diagram for Rotax-Eclipse type Y150B starter

Brushes

The brushes should be inspected at 150-hour intervals to see that they are bearing on the commutator, and that they do not bind in their respective holders. If such periodic examination should disclose worn brushes, they should be replaced immediately. Burning of the commutator easily results from failure to make such replacements in time.

Replacement brushes should be secured from the makers or from an authorised aeroplane service station, as they are of special material, and if inferior brushes are substituted, satisfactory operation cannot be expected.

Brush Springs

The brush springs should also be examined, and if they have lost their tension, they should be replaced. The brushes should be under at least 20 oz. pressure.

Commutator

Do not use emery cloth or rough sandpaper on the commutator. It may be polished with fine sandpaper. Make sure that all sand particles are cleaned out before operating the motor. If the commutator becomes rough or burned, remove the armature, and take a light smooth cut across its face.

Motor Fails to Operate

If the motor fails to operate, the trouble may be in the solenoid switch or the push button. A wire connected across the large terminals of the solenoid switch will make a direct circuit between the battery and starter. If the motor operates with this jumper wire, the solenoid or push button is inoperative.

The bearings are lubricated with a good grade of neutral bearing grease. N.E. ball-bearing grease (as manufactured by Messrs. Edgar Vaughan, Ltd., of Birmingham) or its equivalent is recommended. The gears and clutch are lubricated with a light covering of No. 223 Gredag. It is highly important that no other lubricant is used.

All starter clutches are carefully set prior to despatch, and should not require altering. This setting is determined by the size of the engine on which the starter is to be used, and it requires special equipment. If a change in the clutch setting is required; the starter should be sent to the makers for adjustment. The clutch setting for the N3EM starter fitted to the Armstrong-Siddeley "Cheetah" engines is 240 lb./ft.; the setting for the Y150B starter fitted to the "Gipsy Six" or "Gipsy Major" engines is 200 lb./ft.

Oil Seal

An oil seal is incorporated in all starters to prevent a leakage of oil from the engine crankshaft into the starter housing. Engine oil will slow up the operation of the starter so that its performance is unsatisfactory.

A baffle plate is provided completely to cover the portion of the starter protruding into the crankcase, to protect the starter from oil splash. A leather seal is also assembled within the baffle plate at the back of the starter jaw to protect it in the event of the oil level, for any reason, approaching the opening in the baffle plate.

Dismantling

The construction of the starters is shown in Figs. 5 and 7.

The first operation in dismantling the starter is to separate the front housing from the rear housing by removing the six bolts.

The hand-turning attachment on the N3EM starter must be removed by taking off the five retaining nuts. The locknut on the bevel gear should then be removed, after which the crown gear may be pulled out.

The pinion on the armature shaft can now be removed. Afterwards remove the four screws, and the motor can be withdrawn from the rear housing.

The starter jaw is removed by unscrewing a nut from the operating rod. The barrel can then be removed from the front housing.

Ordinarily it will not be necessary to disturb the clutch adjusting nut on the top of the spline nut, but if it is to be removed, its position in

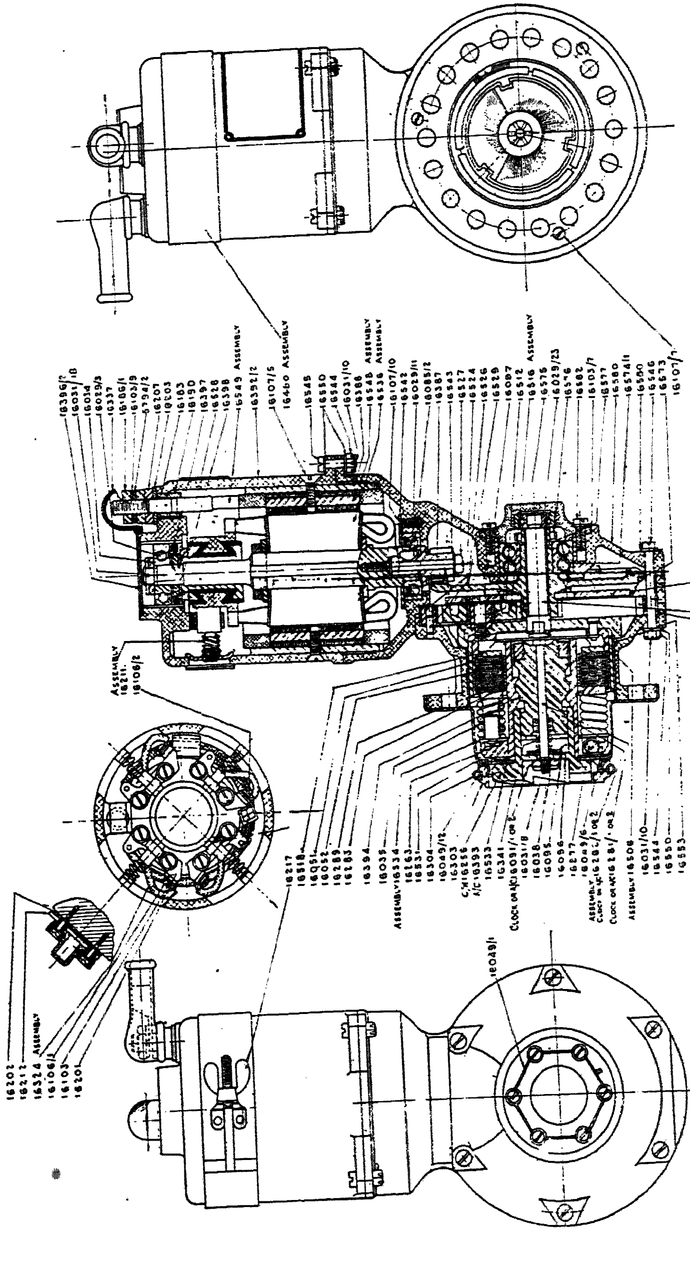

Fig. 7.—SECTIONAL DIAGRAM OF ROTAX-ECLIPSE TYPE Y150B STARTER

regard to the spline nut should be marked, so that it can be assembled again without altering the clutch setting.

Further dismantling can readily be followed from the diagrams.

In reassembling parts, make certain that the tie wire, cotter pins, lock washers, and locknuts are used where required.

ROTAX 1,000-WATT ENGINE-DRIVEN GENERATOR

THIS 1,000-watt generator is an engine-driven four-pole shunt-wound machine which develops 1,000 watts at 24 volts when running at speeds between 4,000 and 6,000 r.p.m.

This machine is provided with a cooling jacket, air being fed through a union, either at the commutator end or one of the sides, whichever is the more convenient, and out on the opposite side. Air from the slip-stream of the aeroplane may be used for this purpose. The central union to the terminal box carries the cable-shielding conduit, which must be used when making connection with the generator. The machine's output would vary considerably with the speed of the engine, and must therefore be used in conjunction with the N5FF regulator.

The generator is obtainable either for clockwise or anticlockwise

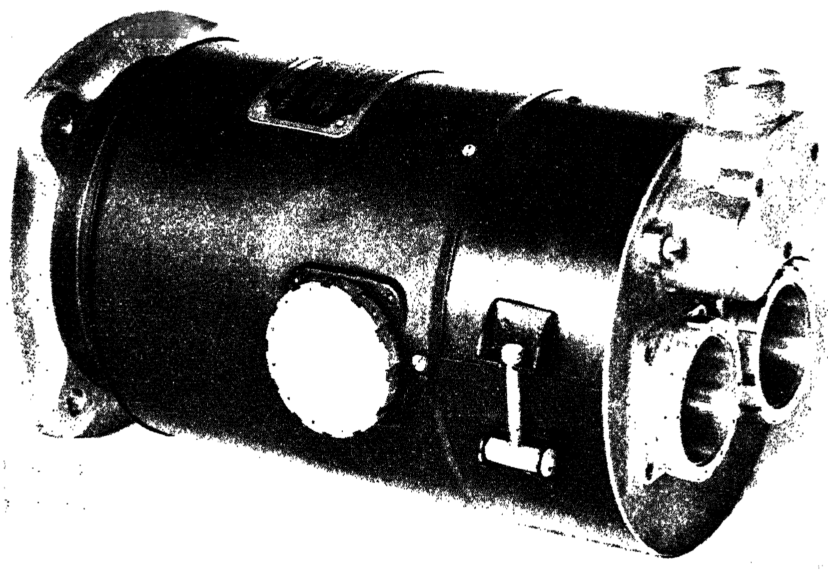

Fig. 1.—ROTAX 1,000-WATT GENERATOR

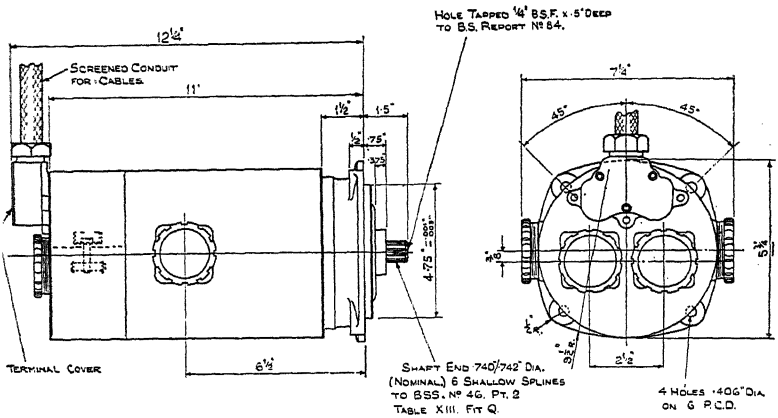

Fig. 2.—INSTALLATION DIAGRAM FOR 1,000-WATT GENERATOR

rotation, this being the direction of rotation of the armature when looking at the driving end of the machine.

Installation

The generator is designed to bolt on to a mounting flange, the pitch diameter of whose bolts is 6 in.; there are four 0·406 in. diameter equally spaced holes in the generator flange (see Fig. 2). The splined driving shaft is protected by a brass ferrule when it is despatched from the factory, and this must of course be removed before mounting the generator.

Care should be taken to see that the coupling is a good fit on the splines, and that the hole into which the generator spigot fits is clear and free from dirt, etc. When the generator has been carefully bolted to its mounting flange, it should be connected via the screened conduit to the regulator. It is desirable that all wiring should be as short and as direct as possible, to eliminate as far as possible volt drop in the conductors.

Care and Maintenance

The generator is sufficiently lubricated prior to despatch, and will require no attention between the 60-hour inspections. No oil or grease must be allowed to gain access to the commutator, as it may cause considerable damage to the commutator and brushes. For this reason it is essential that thin oils are not used in the lubrication of the bearings, which should be lubricated with Edgar Vaughan's Efhco No. 2 Grease.

Brushes

The brushes should be inspected at intervals to see that they are bearing on the commutator and that they do not bind in their holders.

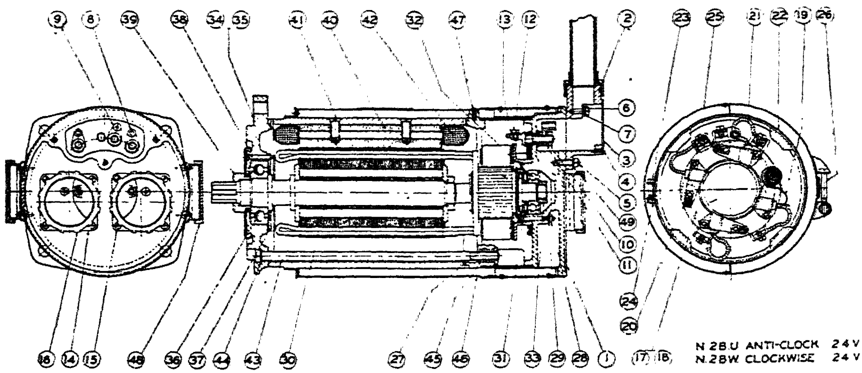

Fig. 3.—DIAGRAM SHOWING ASSEMBLY OF 1,000-WATT GENERATOR

KEY

1. Comm. end frame C/W. connecting rings, etc. ; 2. Cable junction box ; 3. Junction box cover ; 4. Fixing screws for J.B. cover ; 5. Fixing screws for J.B. ; 6. Fixing screws for cable clamp ; 7. Cable clamp ; 8. Terminal tag, positive and negative ; 9. Terminal tag, field ; 10. Terminal nut ; 11. Grover washer for terminals ; 12. Screws for connecting ring lugs ; 13. Washers for item 12 ; 14. Air pipe union ; 15. Fixing screws for air pipe union ; 16. Nut for air pipe union ; 17. Brush rocker assembly, A/C ; 18. Brush rocker assembly, C/W ; 19. Brush spring ; 20. Split pin for brush spring ; 21. Brush with flex, tag and insulation ; 22. Comm. end cover ; 23. Screw for comm. end cover ; 24. Nut for comm. end cover ; 25. Cover band assembly ; 26. Screw for cover band ; 27. Fixing screw for brush rocker ; 28. Nut for item 27 ; 29. Grover washer for item 27 ; 30. Armature complete ; 31. Comm. end grease disc ; 32. Comm. ballrace, Hoffmann ; 33. Armature shaft nut, comm. end ; 34. Driving end frame, C/W ; 35. Driving end frame, A/C ; 36. Driving end ballrace, Hoffmann ; 37. Bearing clamp plate ; 38. Fixing screw for item 37 ; 39. Oil thrower driving end complete ; 40. Yoke and pole pieces, assembled ; 41. Screw for fixing pole piece ; 42. Field coil complete ; 43. Fixing bolt for end frame ; 44. Grover washer for item 35 ; 45. Fixing bolt nut ; 46. Yoke casing assembly ; 47. Fixing screws for item 46 ; 48. Cap for air union ; 49. Grover washer for junction box fixing screw.

If such periodic examination should disclose worn brushes, they should be replaced immediately. Burning of the commutator easily results from failure to make such replacements in time.

Replacement brushes should be secured from the makers or from an authorised aeroplane service station, as they are of special material, and if inferior brushes are substituted, satisfactory operation cannot be expected.

Brush Springs

The brush springs should also be examined, and if they have lost their tension, they should be replaced. The brush-spring pressure should be 14 $\pm$ 2 ozs.

Commutator

When the commutator becomes dirty it may be cleaned with a clean rag moistened in petrol. Should the commutator become burnt, reason-

ably bad cases may be cured by the use of very fine carborundum cloth on the commutator (emery paper must not be used). All dirt must afterwards be brushed off the commutator and brush gear.

Very bad cases must be set up on a lathe and the commutator "skimmed." Care should be taken that as small a cut as possible be set for each operation, and that the tool cuts cleanly, leaving a high polish. The slots between the segments should be freed of any turnings—an old hacksaw blade ground square will make a very serviceable tool.

Failure to Generator

Should the generator fail to generate, the brush-inspection bands should be removed and the brushes inspected to see that they are making proper contact with the commutator, and that the commutator is clean and free from burns. If bedding the brushes and cleaning the commutator produces no results, a voltmeter should be connected across the − ve + ve terminals of the generator.

Should the generator be found to be generating, the rest of the circuit should be traced through for a break or other fault ; if, however, there is no indication of a voltage at the terminals, this may be due to lack of residual magnetism in the pole shoes. To correct this, either lift all brushes or disconnect the wire to the positive (+ ve) terminal and close the cut-out contacts to flash the field, care being taken that the contacts do not stick. If there is still no voltage generated when the generator is run up to normal speed, the field fuse in the switch box should be inspected.

If this is blown, an ammeter, reading to about 10 amps., should be put in place of the fuse in the faulty generator. If the field-current reading of faulty generator on no load exceeds $\frac{1}{4}$–$\frac{1}{2}$ amp. when running between speeds of 6,000–4,000 r.p.m., by a fairly wide margin, a short may have developed on the field. New field coils can be supplied for fitting if absolutely necessary ; great care should be taken to see that they are not damaged when assembling, and that the pole shoes are replaced in their correct position, as they have been ground in position. *This operation, however, should not be attempted unless a pole shoe expander and hand wheel operated screwdriver are available.*

They are marked one dot, two dot, etc., and the tunnel to correspond. The pole shoe screws must be carefully caulked after tightening. When the field has been reassembled, it should be flashed to magnetise it ; see end of " Dismantling " (p. 37).

When inspecting the commutator, should it appear to be badly burnt, this may well cause loss of voltage and the commutator should be skimmed up as above. For details of disassembly see facing page. Should any difficulty be found in remedying any trouble, it is most desirable that the generator be returned to the makers.

The armature windings can be tested from the commutator bars by means of an ohmmeter, and the resistance between each bar should be as

nearly as possible equal. A drop in resistance between any two bars indicates a short on the windings concerned.

When the generator is dismantled for overhaul, the armature and field coils should be tested for shorts, open circuits, and earth. A "Megger" should be used for testing to earth and, when cold, all parts should register infinity. One lead should be connected to the part under test (say the commutator), and the others to earth (the shaft), or if the fields are to be tested the one lead should be connected to the leads of the field, and the other to the yoke. If parts register a value less than infinity when cold, they should be examined for possible earths, and if very low should at once be replaced.

No attempt should be made to rewind the armature should trouble arise in this direction; a new one should be obtained. The connecting rings in the commutator end frame should not be removed, as they are coated with a special insulating varnish, and removal of this will allow carbon dust, etc., to get between them and possibly cause a short circuit.

Should it be necessary to slacken off or remove the brush rocker at any time, it should, on being replaced or tightened, be carefully set at the neutral position, i.e. pole centre.

Dismantling

A sectional view of the construction of the generator is shown in Fig. 3.

The first operation in dismantling is to remove both the brush-inspection bands and then the six jacket screws; next remove the field connections that are attached to the centre terminal lug and to the lug on connecting ring.

The brushes should then be lifted up and kept at the top of their holders by means of their springs, which may be made to press on their sides. The four tunnel bolts may then be removed, and the commutator end casting slipped off. The armature and end plate can then be removed from the yoke. To remove the end plate from the armature, the oil thrower must first be removed, carefully prising up the metal which has been caulked into a shaft spline.

The four screws holding the ballrace plate must then be removed and the end plate can be tapped off.

Unless new ones are to be fitted, the bearings should not be removed from the shaft otherwise than with a ballrace extractor.

The brush rocker may be taken off its spigot by undoing the nut and the locking washers.

Before reassembly, all parts should be thoroughly washed in benzine and the races regreased. To re-assemble, follow the reverse order to dismantling, making certain that all split pins, lock washers, and nuts that are required are used and that all previously caulked screws are recaulked.

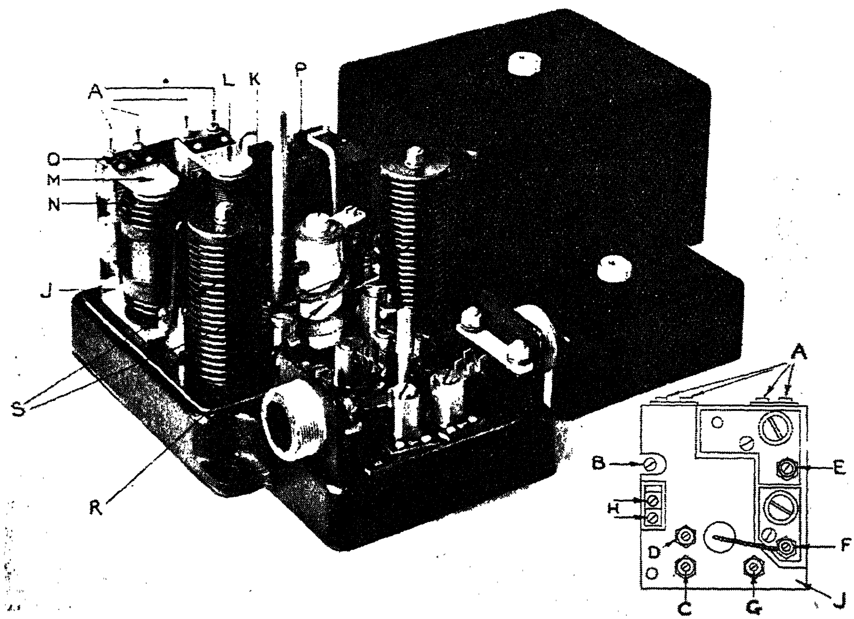

Fig. 4.—Rotax-type N5FF regulator

Key

A. Armature fixing screws ; B. Adjustable regulator contacts ; C. Regulator voltage setting screws ; D. Regulator voltage setting auxiliary screws ; E. Adjustable main cut-out contacts ; F. Adjustable auxiliary cut-out contacts ; G. Cut-out voltage setting screws ; H. Screws holding regulator fixed contacts ; J. Main regulator frame ; K. Regulator coil ; L. Regulator armature ; M. Output armature ; N. Bobbin core ; O. Cut-out armature regulating stop ; P. Condenser ; R. Resistance (field parallel) ; S. High frequency chokes.

To be sure that field yoke and pole shoes are properly magnetised after assembly, lift all brushes, and flash the field by connecting the positive field terminal F to the positive side of a 12-volt battery, and touching momentarily the negative side of the battery to the negative terminal of the generator.

ROTAX C.V. SYSTEM AS USED ON SHORT "EMPIRE" BOATS

Description and Running Instructions

The underlying principles of the compensated voltage control system are to make the dynamo output independent of the speed at which it is driven, and to maintain the voltage of the dynamo always slightly in excess of the back pressure or voltage of the battery.

The first principle holds only so long as the dynamo speed has passed the minimum value at which the full output can be produced, and the

second ensures a flow of charging current when the battery is connected with the dynamo. This second principle is further elaborated to the extent that the excess voltage of the dynamo over the battery is made greater and greater as the battery becomes discharged, and less and less as the battery becomes more highly charged. This ideal condition of an automatic adjustment of the charging current ensures the battery being fully charged without risk of overcharging, thus lengthening the life of the battery.

When the battery is in a low state of charge, it offers a low back pressure, and receives a comparatively high charging current, and as it becomes charged, offering an increasingly high back pressure, the charging current falls. This action is so regulated that, when the battery is in a very low state and badly needs a good charging, the initial rate of charge is almost as high as the battery can safely withstand, rapidly removing the battery from the danger of sulphation.

As the state of the battery improves, the charging current diminishes until, when the battery begins to gas, the charging rate has dropped to a figure well below the limit at which any harm can possibly arise through too profuse bubbling.

A further result of the principles applied in the compensated voltage control system is that the dynamo has to deliver, and does actually deliver, only sufficient current to meet the load and requirements of the battery adequately.

Voltage Control Box, Type N5FF

This is used in conjunction with the 1,000-watt generator, and consists of the generator voltage regulator and cut-out, housed together with the series control resistance, two H.F. chokes, and a condenser under one cover.

Regulator

The regulator has a single pair of contacts arranged so as to insert a resistance in the field circuit of the generator during the regulating period, thus controlling the generator output. The resistance is wound on the regulator bobbin in such a manner that the magnetic influence set up by the winding opposes the shunt and series windings, causing the contacts to close. The object of this arrangement is to maintain a high-frequency operation.

Cut Out

The cut out is an automatic switch which connects the battery to the generator when the latter is running sufficiently fast to charge the battery, and disconnect it again when the speed drops too low, thus preventing current reversing through the dynamo windings.

The high-frequency chokes, which are connected in series with the generator and battery, suppress, in conjunction with the condenser, H.F.

interference with the radio apparatus which would otherwise result.

Located under a smaller cover, with a large thumbscrew to make them readily accessible, are the terminals, cables being led in through special shielded cable tubes by means of the unions placed one on either side of the box.

All control boxes are carefully adjusted, tested, and finally sealed, and attempts should not be made to carry out any adjustments unless some tuition has been received on the subject, since the satisfactory operation of the equipment depends absolutely on the correct functioning of the regulator.

To adjust the Regulator Setting

It is not advisable to remove or loosen the regulator armatures, but, should this unavoidably become necessary, the following operations should be carried out in the sequence given (refer to Fig. 4):

(1) Slack off screws A attaching the flat spring to the frame.

(2) Slack off adjustable contacts B.

(3) Slack off pressure-spring adjusting screws C and D.

(4) Press armature down to core and back against frame. It is essential that there is no air gap between core or frame.

(5) Tighten screws A.

(6) Adjust contact B, so that the gap between core and armature lies between 1·2 and 1·4 mm., measured at armature tip.

Electrical Setting

The required open voltage, 29·2–29·4 volts, is obtained by adjustment of screw C. To raise the voltage, screw downwards; to lower, unscrew upwards. The stop screw D should then be adjusted until it touches the bronze armature spring, and then slacked back $1\frac{1}{2}$ turns to leave a gap. The generator should be stopped and restarted several times in order to make sure of the correct adjustment.

Cut Out

Settings are effected in a similar manner to the regulator setting, and it is permissible to remove the armature if necessary for contact cleaning. When the armature is replaced or needs adjusting, the following operations should be carried out in sequence (refer to Fig. 4):

(1) Slack off screws A attaching flat spring to frame.

(2) Slack off screws to separate main contacts E and auxiliary contacts F.

(3) Insert feeler gauges 0·1 mm. thick between armature and frame.

(4) Press armature down on to the core and back against feeler so that feeler is gripped firmly.

(5) Tighten clamping screws A.

(6) Screw down main contact E until gap between the armature tip and core is 0·7 mm. when contacts are closed.

(7) Set armature gap with contacts open to 1·6 mm. by bending the armature stop O gently, or by tapping lightly with a screwdriver.

(8) Adjust auxiliary contacts F to close when main contacts are still 0·2 mm. open.

(9) Adjust screw G so that armature operates at about 3 volts below minimum open-circuit regulator voltage, i.e. 25·8–26·2 volts.

In the unlikely event of the contacts being found to be in a dirty condition, they should be cleaned with very fine carborundum paper and a chamois leather dipped in 95 per cent. pure ethyl alcohol.

ROTAX 500-WATT ENGINE-DRIVEN GENERATOR

THIS model is virtually the Air Ministry engine-driven generator (A.M. Ref. Nos. 5C/563 and 5C/562) to Specification E. and I. 350, and is now released for civil aviation by permission of the Air Ministry.

This generator has many interesting features. A special regulating system is incorporated, giving a substantially constant output over a speed range of 4,000–6,000 r.p.m. This is effected by a special control field wound to oppose the main field produced by shunt and series windings designed to give level compounding. This control field is connected in the battery-charging circuit ; therefore, increased generator speed is followed by a reduction in total flux, the voltage being maintained at constant value. The main load is not connected through this control

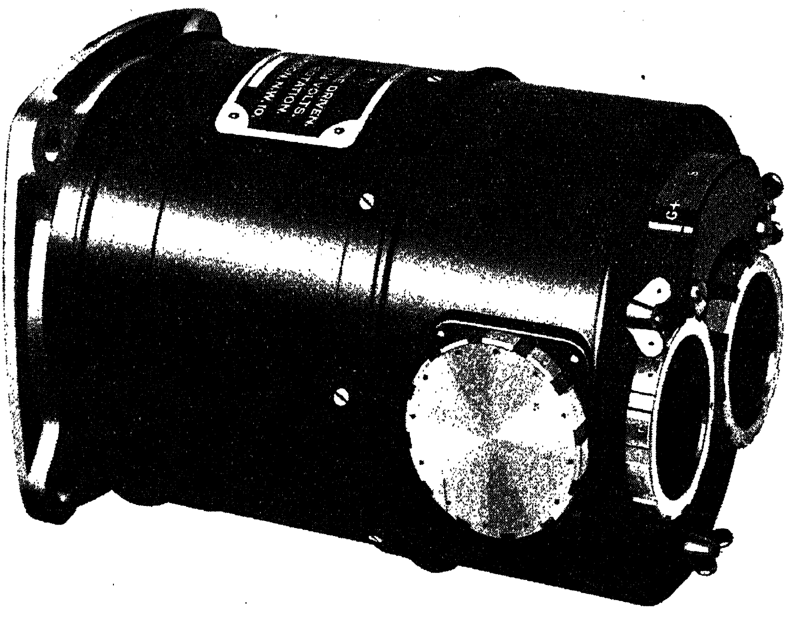

Fig. 1.—ROTAX ENGINE-DRIVEN GENERATOR, TYPE AT178, 12-VOLT, 500-WATT

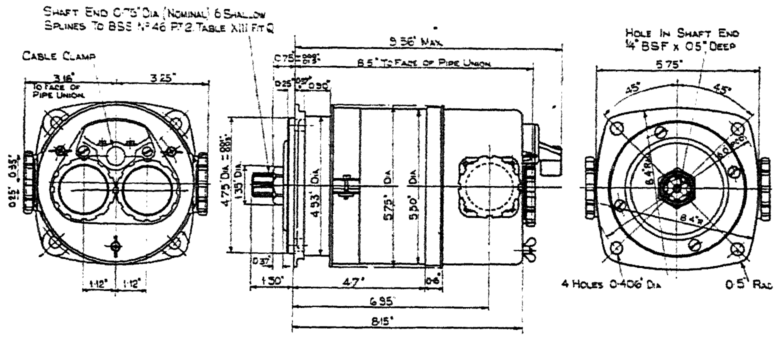

Fig. 2.—Installation diagram for 500-watt generator

field so that charging conditions are independent of the total load on the system.

To avoid overcharging on long runs during which the battery is not being used, a resistance is provided which is switched into the shunt field of the generator to cut down the charging current.

The regulating system, obviating the necessity for any type of Tirrell or vibrating contact regulator, renders it much less liable to interfere with radio reception on the aeroplane.

Since breaking of the control field would mean a rise in voltage, it is important to switch the generator off in a special manner, first of all breaking the shunt field and finally breaking the control field after the battery negative has been joined to negative of line.

To accomplish this in the correct sequence, the Air Ministry type two-charge switch (A.M. Ref. No. 5C/585) can be supplied, this switch also being adapted to switch into circuit the special resistance unit (A.M. Ref. No. 5C/586) mentioned above, this being inserted in the shunt field of the generator.

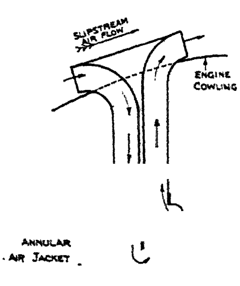

Fig. 3.—Diagram of cooling system

For civil purposes, however, it has been found desirable in many instances to use a composite form of switchbox to contain the control switches for the generator, the resistance unit, together with voltmeter, ammeter, and fuses, and the Rotax switchbox P.T. 16/4 has been

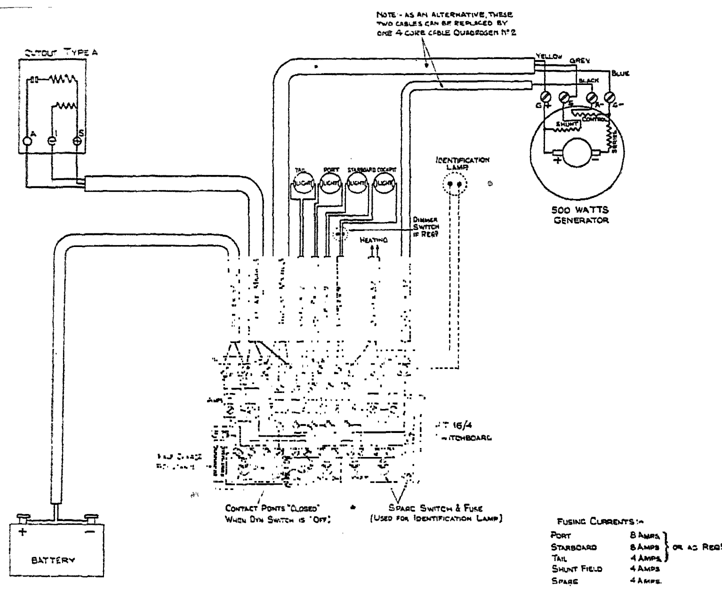

Fig. 4.—DIAGRAM OF SINGLE-GENERATOR LAYOUT

specially developed for this purpose. This switchbox also carries fuses and switches for the various circuits, such as navigation lights, cockpit lights, cabin lights, etc.

The generator is provided with an outer cooling jacket through which air is fed by pipes from the slipstream.

An automatic cut out has to be used, a suitable one being the Rotax type A.

Installation

The generator is designed for bolting to a standard 6-in. generator mounting flange, and is provided with four 0·406-in. diameter equally spaced holes for this purpose (see Fig. 2). The splined shaft is protected during transport by a brass ferrule, which must be removed before mounting the machine.

When the generator has been mounted on to the engine, the air pipes for collecting cooling air from the slipstream should be bolted on to the jacket, using either the end or side connections, whichever is the more convenient (see Fig. 3); 46 cubic feet of free air per minute should be available for cooling purposes.

As described previously, two types of switches for charge and half charge are available.

The alternative method of connection—and the most convenient on commercial aeroplanes—is illustrated in diagram Fig. 4, using the Rotax

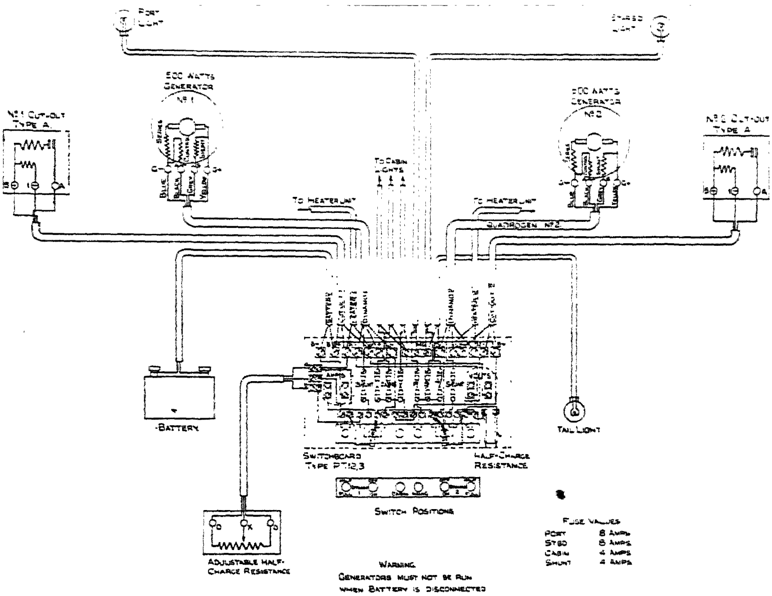

Fig. 5.—DIAGRAM OF TWO-GENERATOR LAYOUT

P.T.16/4 switchboard. Fig. 5 illustrates a two-generator layout, using Rotax P.T.12/3 switchboard.

All conductors should be kept as short as possible and the specified cable used.

With the half-charge switch in, the charging current should be in the neighbourhood of $2\frac{1}{2}$ amps.; this as a maximum.

Care and Maintenance

The generator is sufficiently lubricated prior to despatch and should require no attention for a considerable period. No oil or grease must be allowed to get on the commutator as it will cause considerable damage to the commutator and brushes. For this reason it is essential that thin oils are not used in the lubrication of the bearings, which should be packed with Edgar Vaughan's Efhco No. 2 Grease, at major engine overhauls.

Brushes

These should be inspected at 40-hour inspections to see that they are bearing on the commutator and that they do not bind in their holders. If such periodic examination should disclose worn brushes they should be replaced immediately. Burning of the commutator and insulation easily results from failure to make such replacements in time. See also that

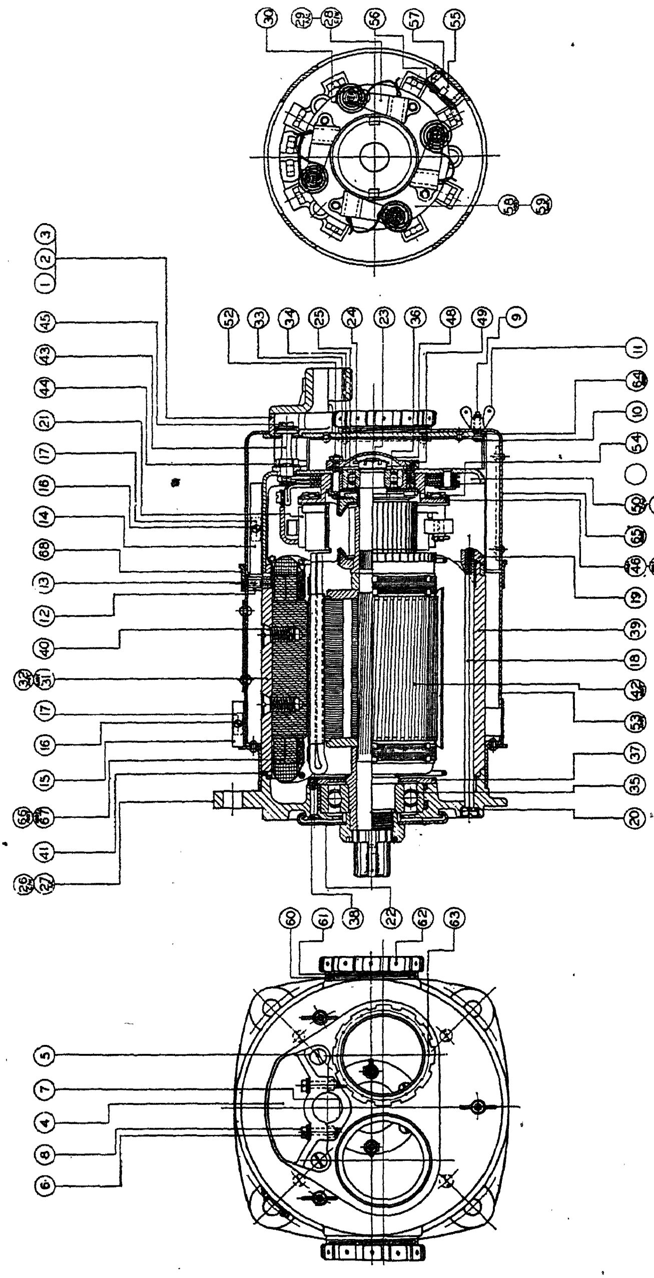

Fig. 6.—SECTIONAL DRAWING OF ROTAX 500-WATT GENERATOR
(See key on facing page.)

the brushes neither bind nor are yet very loose in the holders. When new brushes are fitted they should be bedded in to the contour of the commutator with fine carborundum cloth.

The brush springs should also be examined, and if they have lost their tension they should be replaced. The brush spring pressure should be 14 ± 2 ozs.

Commutator

If the commutator is rough and dirty it should be cleaned with fine carborundum cloth. If the commutator is extremely rough the armature should be removed and set up in a lathe, and a smooth fine cut taken with a sharp tool. The micas should then be cut, using a tool slightly wider than the micas to ensure that none is left on the edges of the slot. A suitable tool can readily be made from an old hack-saw blade. The commutator should then be polished with fine carborundum.

If at major engine overhauls, when the generator should be dismantled, the ballraces are found to be rough, they should be removed and replaced with new ones. They should not be removed except for replacement, but should be washed out in petrol and blown with compressed air to dry out, and then packed with grease before reassembly.

Testing at Major Overhauls

When the generator is dismantled for overhaul the armature and field coils should be tested for shorts, open circuits, and earth. A "Megger" should be used for testing to earth, and when cold, all parts should register infinity. One lead should be connected to the part under test (say the commutator) and the others to earth (the shaft), or if the

KEY TO FIG. 6

1. Terminal shroud; 2. Stud for shroud; 3. Nut for shroud; 4. Terminal cover; 5. Screw for cover; 6. Double spring washer; 7. Cable clamp; 8. Clamp screws; 9. Stud for end plate; 10. Locking plate for stud; 11. Wing nut for comm. end casing; 12. Spacing studs for yoke casing; 13. Screw for fixing end plate; 14. Comm. end cover; 15. Strap for yoke casing; 16. Screws; 17. Nuts; 18. Bolt for fixing end frames; 19. Claws; 20. Spring washers; 21. Brush with flex and tag; 22. Oil thrower complete; 23. C.E. bearing locknut; 24. Split pin; 25. Gasket for bearing-cap C.E.; 26. Drive end frame C/W; 27. Drive end frame A/C; 28. Brush holder C/W; 29. Brush holder A/C; 30. Brush spring; 31. Assembly of field magnets A/C; 32. Assembly of field magnets C/W; 33. Nuts for bearing cap; 34. Tab lock washers; 35. Bearing $1 \times 2\frac{1}{4} \times \frac{5}{8}$ in. Hoffmann LS-10 ..fit; 36. Bearing $\frac{1}{2} \times 1\frac{5}{16} \times \frac{3}{8}$ in. Hoffmann LS-5 ..fit; 37. Bearing cap; 38. Screws for cap; 39. Magnet yoke; 40. Screw for fixing pole piece; 41. Dowel; 42. Armature complete; 43. Terminal (end); 44. Lock washer for terminal; 45. Combined screw and washer; 46. Assembly of brush rocker A/C; 47. Assembly of brush rocker C/W; 48. Bearing-cap C.E.; 49. Screw for bearing cap; 50. Comm. end frame with connecting rings C/W; 51. Comm. end frame with connecting rings A/C; 52. Rocker fixing studs; 53. Yoke casing assembly; 54. Locking plate; 55. Condenser; 56. Packing piece; 57. Fixing screws; 58. Assembly of brush gear and end frame C/W; 59. Assembly of brush gear and end frame A/C; 60. Rivets union; 61. Air pipe union; 62. Cap for union; 63. Nut for union; 64. End plate assembly; 65. Casing comm. end assembly; 66. Assembly of field coils complete C/W; 67. Assembly of field coils complete A/C; 68. Spigot ring.

fields are to be tested one lead should be connected to the leads of the field and the other to the yoke. If parts register a value less than infinity when cold they should be examined for possible earths and if very low should at once be replaced.

Shorts are best detected by means of a "growler," but failing this a careful inspection should be made of the commutator to ensure that no particles of copper or carbon dust are shorting across the insulation between segments.

Brush springs should again be checked up (see Brushes, p. 45) and rejected if weak. When the machine is reassembled the shunt field should be flashed with a battery to ensure that it is properly magnetised. For this purpose a twelve-volt battery should be used, the brushes being lifted off the commutator when flashing and the leads being connected momentarily to the grey and yellow terminals, the yellow being the + ve.

Dismantling

The jacket end cover should first be removed by taking off the three wing nuts. Then the brush inspection strap. The brushes should be pulled up off the commutator to avoid damaging them when withdrawing the armature.

The field connections to the commutator end frame should then be taken off one by one and tagged to facilitate reassembly. The four yoke bolts may then be removed from the driving end frame. The end frames and yoke can then be separated.

When removing the armature from the driving end frame it should be noted that the oil slinger also acts as a lock nut and that it is caulked down into one of the splines of the shaft. This should be gently prised up before removing the slinger. Further dismantling is obvious with reference either to the machine itself or to Fig. 6.

ROTAX-ECLIPSE INERTIA STARTERS

HAND OR COMBINATION HAND AND ELECTRIC

THE basic principle of all "Eclipse" inertia starters is the storage of energy in a small flywheel by accelerating it to a high speed, either manually or electrically. The energy thus stored is expended in rotating the engine crankshaft.

Transmittal of the kinetic energy of the rotating flywheel to the engine is accomplished through a multiple-gear reduction, adjustable torque overload release, an engaging mechanism, and driving jaw.

Advantages of Inertia Starting

The outstanding advantages obtained in the adoption of the inertia principle of engine starting are :

Minimum Weight.—In proportion to the cranking torque capacity of the starter.

High Initial Cranking Speed.—A high, momentary cranking speed is imparted to the engine, thereby ensuring the deliverance of fuel to the cylinders and also permitting starting with a greater degree of spark advance than is otherwise possible. Conditions are thus ideal for securing a quick start under adverse conditions.

Acceleration Independent of Engine.—The actual cranking of the engine does not take place until after the proper starter flywheel speed has been obtained by either manual or electrical acceleration. Therefore, the amount of effort which is required to accelerate the flywheel is constant and independent of engine stiffness, size, and conditions caused by atmospheric temperatures. These varying factors have therefore no effect on the operation of the starter prior to engagement with the engine.

This feature is particularly advantageous during cold weather, and also in the operation of electrically accelerated starters, as the amount of current required remains unchanged or uninfluenced by variations in engine condition.

In this respect, the inertia starter differs from the direct-cranking electric starter or hand-turning gear, in that the current or effort required to operate the latter is directly proportionate to the size and stiffness of the engine, the condition of the battery, etc. In the case of a very cold engine, the current draw of the direct cranking starter will in most cases average considerably more per start than with the inertia starter.

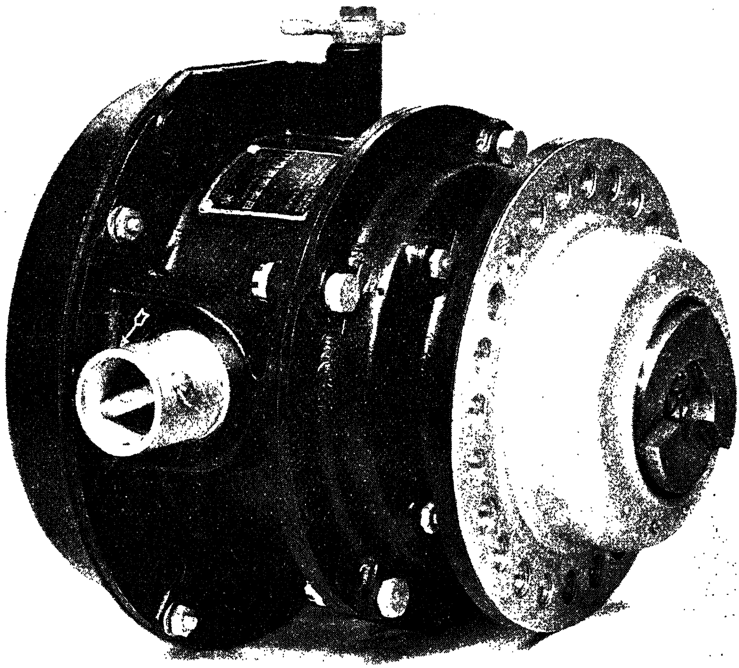

Fig. 1.—Rotax-Eclipse Series XI inertia starter

This is of the concentric inertia type and although particularly adaptable to engines of the radial type is equally suitable for starting those with cylinders in line.

ROTAX SERIES XI INERTIA STARTERS

Series XI Inertia Starter

The Series XI hand or combination hand and electric starters are of the concentric inertia type. Although particularly adaptable to engines of the radial type, they are equally suitable for starting those with cylinders in line, and are suitable for engines up to and including 700 horsepower. They can be obtained for either clockwise or anti-clockwise rotation. Starter rotation is taken facing the starter jaw.

Construction

The Series XI inertia starter is designed for mounting on a standard 6-in. SAE mounting flange, and incorporates in its design provisions for mounting an electric accelerating motor with suitable control devices. The construction of the starter is as follows :

Manual cranking torque is applied to a ball-bearing mounted crank-

shaft. Torque is transmitted through a pair of bevel gears to the driving barrel, on which are mounted a set of planetary gears. The planetary gears, rotating in a fixed internal gear, transmit torque to a sun pinion and gear which are integral. From this point, torque is transmitted to an intermediate pinion and gear which are integral, thereby turning a pinion which is keyed to the flywheel.

In this manner, energy is stored in the flywheel, which is accelerated to a speed of approximately 15,000 r.p.m. The energy, thus stored, is transmitted from the flywheel to the starter jaw in a reverse direction through a torque overload release, which consists of a multiple disc clutch under adjustable spring pressure. The torque is transmitted from the clutch to an internally threaded nut member within, which operates a longitudinally movable screw shaft, splined to the starter jaw. The starter jaw is engaged with the engine jaw by means of a meshing rod, which is controlled from a bell crank located on the exterior of the starter. When the engine starts, the rotation of the engine jaw is faster than that of the starter jaw, and the latter is automatically disengaged.

When electrically operated, the flywheel is accelerated to the required speed by a motor, mounted on the flywheel housing, which drives directly without gearing.

A baffle-plate oil-seal assembly, completely covering the portion of the starter protruding into the engine crankcase, is incorporated in these starters to prevent leakage of engine oil into the starter housings.

Accelerating Motor for Inertia Starters

Motors are available for either 12- or 24-volt operation. Motor rotation is opposite to starter rotation for Series XI starters.

Construction

The electric motor is series wound for 12- or 24-volt operation, and expressly designed for high-speed requirements. The motor is a separate unit, the housing of which is bolted to the flywheel end of the starter. A motor bracket, bolted to the flywheel housing, is provided for attaching the motor to the starters. No other mechanical connections exist until the motor has been brought into operation.

The ball-bearing mounted motor armature is connected to the flywheel only during the period of flywheel acceleration, its connection and disconnection being provided for by an automatic mechanism. Friction and drag on the starter, when hand operated, is thereby entirely eliminated.

The automatic engaging and disengaging mechanism consists of a jaw designed to mesh with a similar jaw, attached to the starter flywheel. As the armature shaft begins to rotate, the jaw automatically advances on the spiral thread until fully engaged with the flywheel jaw. Automatic disengagement occurs when the motor circuit is broken. For

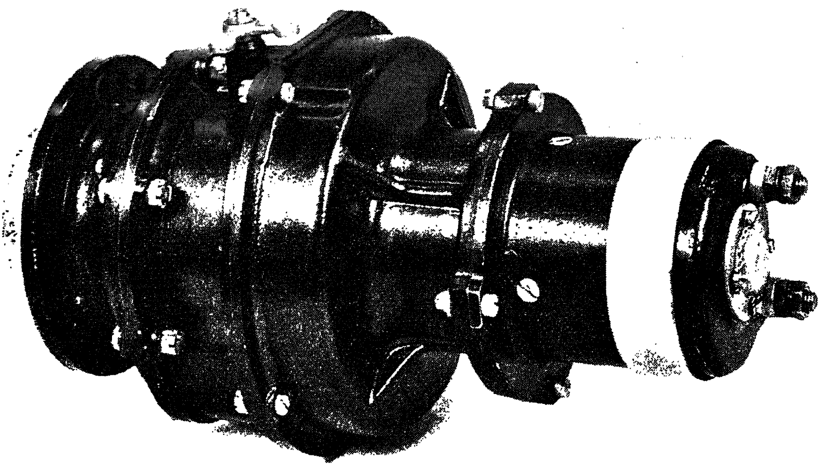

Fig. 2.—Rotax-Eclipse Series XI inertia starter fitted with Y-100 accelerating motor

additional information relative to motor construction, refer to the cross-sectional drawings.

Hand-crank Assembly

The hand-crank assembly consists of two units, a removable crank handle and the extension assembly, fastened to the starter crankshaft, the crankshafts being fitted with an internally tapered bore at their outer end. The extension assembly is made from heat-treated steel tubing, tapered at the drive end and reinforced with a hardened-steel plug. The drive end of the extension assembly is secured to the starter crankshaft with a ¼-in. diameter bolt, nut, and cotter pin. The bolt is a snug fit in the crankshaft and a clearance fit in the extension assembly, thereby permitting universal action between the two, should slight misalignment of the extension occur.

The crank end of the tubing is permanently pinned to a hardened-steel piece, which engages with the hand crank by means of a spiral slot. Disengagement after cranking is automatic. The extension assembly is supported by a ball bearing (not furnished) mounted on the side of the fuselage and applied to the large diameter of the extension assembly at the crank end.

Booster Coil

The Rotax battery booster coil is recommended for use with Series XI combination hand and electric starters to facilitate engine starting under

all conditions. Booster coils may be used in place of hand magnetos for hand inertia starters in installations where battery current is available. Booster coils are available for 12- and 24-volt systems, and are screened against radio interference.

Construction

The battery booster coil consists of a primary and secondary coil wound on a soft-iron core and a vibrating contact operated by and in the primary circuit.

When the primary circuit of the coil is connected with the battery the primary coil magnetises the soft-iron core, causing it to attract the vibrating contact and open the primary circuit. The core immediately demagnetises and allows the contacts to close. This make and break in the primary circuit continues so long as the booster coil is connected to the battery. During the portion of the cycle when the contacts are open, the condenser, connected across the contacts and the primary coil, forms a resonant circuit, which induces a high voltage in the output or secondary coil circuit. The use of a condenser of proper capacity decreases arcing of the contacts, thereby increasing their length of life.

When using booster coils with hand-inertia or electric-inertia starters, where the starter jaw is manually meshed with the engine jaw, the booster coil is connected through an external pull switch to the lever of the starter, so that the booster coil operates automatically when the starter is meshed. However, when a booster coil is used in conjunction with an electric inertia starter, equipped with a solenoid meshing device, the external pull switch is eliminated and the booster coil is connected in the meshing device circuit, so that operation occurs during the cranking period only.

CONTROL DEVICES FOR ELECTRIC INERTIA STARTERS

Solenoid Starting Switch

The solenoid starting switch is designed for use in conjunction with electric inertia starters for closing the circuit to the starter motor. Switches are available for either 12- or 24-volt operation.

Engagement of Starter

When engaging a starter manually, a light-duty, single-contact push-pull switch and a solenoid relay or starting switch are used. In this type of installation, the push-pull switch is mounted on an instrument panel or at any other point within convenient reach of the pilot. The solenoid starting switch or relay is mounted on and electrically connected to the starter unit. The connection of the light duty switch to the solenoid starting switch or relay is such that closing of the switch circuit energises the coil of the solenoid relay, which automatically closes the circuit from

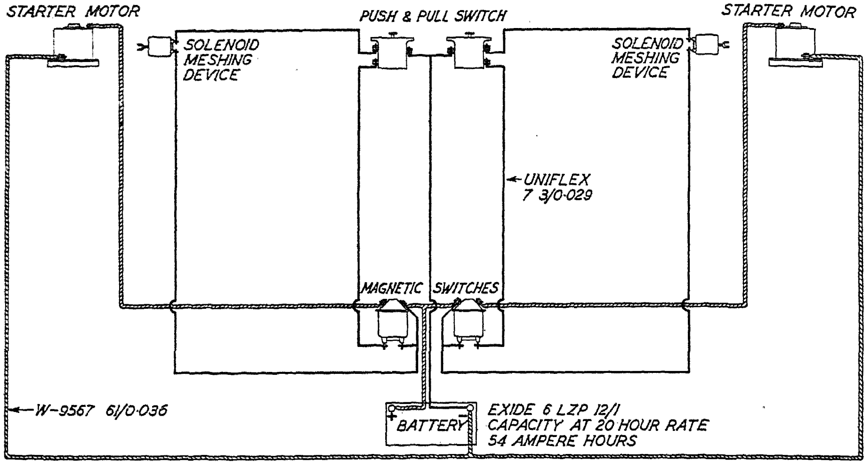

Fig. 3.—Wiring diagram for Rotax-Eclipse electric inertia starters

the battery to the starter motor. When the starter flywheel has been accelerated, the handle of the switch is pulled outward, thus opening the motor circuit and mechanically engaging the starter jaw with the engine jaw. The mechanical engagement is effected by means of a flexible cable connected between the end of the switch plunger rod and the starter engaging clevis.

INSTALLATION OF HAND INERTIA STARTERS

Before installing the starter, remove the dust cover mounted at the forward end and over the starter jaw. Detach the engine crankcase plate and gasket covering the starter drive and mounting flange. Wipe the mounting flange clean and replace the gasket. Examine the end of the engine crankshaft, and ascertain if the engine jaw and starter jaw are of the correct rotation for proper engagement. With the engine-flange gasket in place, the distance from the engine mounting flange to the outermost part of the engine jaw should be $1\frac{1}{16}$ in. The clearance between the engine jaw and starter jaw should be $\frac{3}{32}$ in. when the latter is fully retracted.

The mounting flange of the starter is provided with twenty-four (24) mounting holes that permit locating of the crankshaft at 15° intervals to facilitate clearance of structural members.

Hand-crank Extension

Before installing the hand-crank extension assembly, check direction of cranking as being correct for starter installed.

To install the extension assembly, place the tapered end of the exten-

sion in the tapered socket of the starter crankshaft. Insert the $\frac{1}{4}$-in. diameter bolt, nut, and cotter pin.

It is necessary, when installing the crank extension, to provide an externally mounted support bearing. This bearing is applied to the large diameter, between the pins, at the crank end of the extension assembly. In all installations the bearing used must be rigidly mounted and have an inside diameter of approximately $\frac{1}{16}$ in. greater than the outside diameter of the extension. This will facilitate oiling, and allow $\frac{1}{32}$-in. clearance should slight misalignment of the cranking extension occur. A ball bearing of the self-aligning type is recommended for this purpose. Be sure that the extension is properly aligned and turns without binding.

Caution.—All crank pins and bolts supplied with the crank-handle assembly are of heat-treated chrome-nickel steel, and no pins or bolts other than those furnished should be substituted.

Combination Hand and Electric Starters

Installation procedure is the same as outlined under "Hand Inertia Starters"; in addition, electrical connections must be made in accordance with wiring diagrams.

CONTROLS AND ACCESSORIES

Hand Inertia Starter (without Booster Coil)

A manually operated pull cable or rod is used to engage the starter after flywheel acceleration. The pull cable or rod is secured to the bell crank on the starter, and may be installed in any convenient location on the interior or exterior of the plane.

Hand Inertia Starter (with Booster Coil)

When using a booster coil in conjunction with a hand inertia starter, connect a pull switch between the pull cable or rod and the starter bell crank to close the booster coil circuit when the starter is meshed.

The booster coil is mounted in any convenient location and the high-tension line connected to the booster terminal provided on the service magneto with 7 mm. metal-braided high-tension cable. Connect the booster-coil switch in the positive side of the battery circuit between the battery and one of the low-tension booster-coil terminals. Connect the other low-tension terminals to the negative side of the battery; for wire sizes refer to the wiring diagram.

Combination Hand and Electric Starter (Remote Control System with Manual Meshing)

A solenoid switch remote control system is recommended for use with combination hand and electric starters, when the starter is located at some distance from the control switch. In this type of installation a solenoid switch is located as close to the starter as possible, and is actuated

by a single-contact push-pull switch located in the cockpit. With this type of installation a pull cable or rod connected to the push-pull switch is used to mesh the starter after the flywheel has been accelerated to its proper speed. The booster coil may be mounted in any convenient place, and should be connected in the same manner as outlined above. For wire sizes, refer to wiring diagram.

Caution.—Make certain that engaging cables or rods have sufficient slack to permit complete retraction of the starter jaw by the clevis spring, otherwise the jaw will not seat firmly against the oil-seal leather, and leakage of engine oil into the starter will occur, thus seriously affecting starter performance. If excessive friction is present in the engaging linkage, an external spring should be added to assist in retracting the starter jaw.

Cable lengths in the main starter circuit should be kept as short as possible to minimise voltage drop, as well as to decrease weight of cable used. All cable ends should be securely soldered to terminals and completely covered with rubber nipples or tape, to prevent accidental short circuit. Battery terminals should be covered with vaseline to prevent corrosion.

Important.—Mount booster coils in such a manner that a good connection exists between the housing and earth.

Conversion of Hand to Electric Type

Early-production Series XI starters incorporate a plain flywheel, and are not readily convertible to the electric type. However, later production models have drilled flywheels for detachable jaws, which simplify conversion to the electric type. If the starter is equipped with a plain flywheel, a new flywheel with jaw assembled must be installed.

OPERATION

The starting ability of an inertia-type starter depends upon the energy stored in the rotating flywheel. The starter is designed to operate with the flywheel rotating at approximately 15,000 r.p.m., and this speed should not be exceeded when energising the flywheel.

Inertia starters have a protective clutch designed with alternate steel and bronze discs. The purpose of the clutch is to protect the starter during back fire of the engine or under excessive load. In the case of a very cold engine, energy stored in the flywheel may be dissipated to a certain extent in the clutch, and the engine should by some means be loosened up before the starter can be expected to function properly, preferably by turning over the airscrew by hand.

Manual

For best results in starting, prepare engine in accordance with manufacturer's instructions, and examine starter-engaging mechanism to ascertain that the starter jaw is in the disengaged position. Gradually

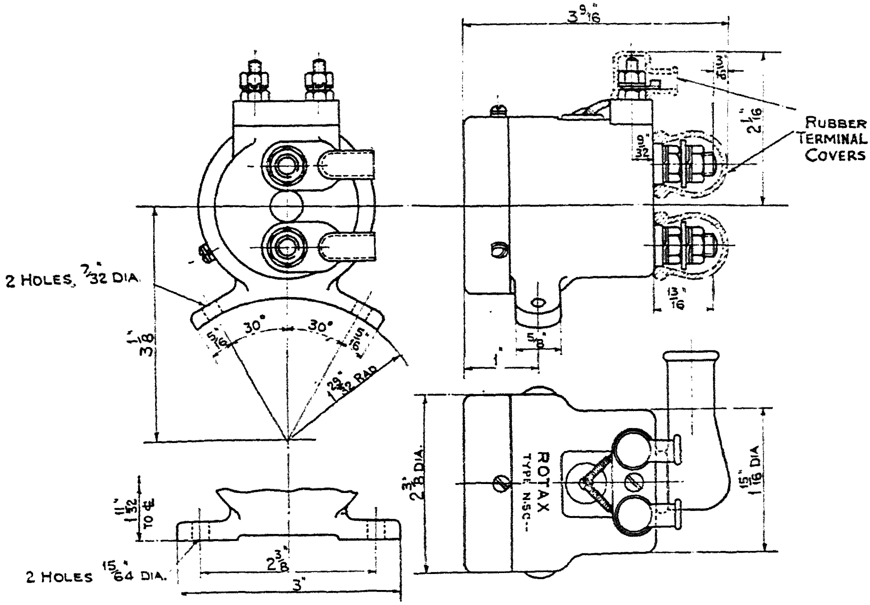

Fig. 4.—Outline of solenoid starter switch

accelerate the hand crank to a speed of approximately 75 to 80 r.p.m. Disengage crank handle and pull the control rod to mesh starter with engine. Return control rod or cable to original position upon firing of the engine. Starter disengagement is automatic upon firing of the engine. If the engine fails to start, repeat the above procedure.

Caution.—In case disengagement of the starter and engine jaws did not occur, turn the airscrew by hand (ignition off) about $\frac{1}{3}$ or $\frac{1}{2}$ of a revolution in its proper direction of rotation to release the starter jaw. In some cases, the starter jaw may be disengaged in starters using a pull rod, by manually returning the rod to its disengaged position.

The booster coil circuit of hand starters should be closed during the time the starter is meshed and the circuit broken when the engine starts.

Electrical

For best results in starting, prepare engine in accordance with manufacturer's instructions, and examine starter-engaging mechanism to ascertain that the starter jaw is in the disengaged position. To mesh starter jaw properly with engine jaw the switch or control-rod handle should be pulled out very quickly.

Do not operate the starter either manually or electrically while the starter and engine jaws are engaged.

If a booster coil is used with this type of installation, close the booster-

coil circuit during the meshing period only. The circuit should be opened when the engine fires.

EQUIPMENT TROUBLES AND REMEDIES

Trouble	*Possible Cause*	*Remedy*
A. Electric motor operates, but does not engage, flywheel.	(1) Motor jaw binding on armature shaft.	(1) Clean and lubricate. See "Major Overhaul Procedure."
	(2) Motor rotation incorrect.	(2) Replace motor.
B. Engine-oil leakage into starter.	(1) Insufficient slack in engaging linkage, preventing complete retraction of starter jaw against leather.	(1) Provide sufficient slack to permit seating of the jaw. See "Installation."
	(2) Excessive friction in engaging linkage, preventing retraction of starter jaw.	(2) Incorporate auxiliary spring in engaging linkage to assist in retracting jaw. See "Installation."
	(3) Worn oil-seal leather in baffle plate.	(3) Replace as instructed under "Major Overhaul Procedure."
C. Free-running time too low.	(1) Engine-oil leakage into starter.	(1) Disassemble, clean, lubricate, and replace worn oil seals as instructed under "Service Inspection and Maintenance" and "Major Overhaul Procedure."
	(2) Improper lubrication.	(2) Disassemble and lubricate as instructed under "Lubrication" and "Major Overhaul Procedure."
	(3) Barrel adjusting nut adjusted too tight.	(3) Adjust as instructed under "Major Overhaul Procedure."
	(4) Ball bearings worn or rough turning.	(4) Disassemble and replace as instructed under "Major Overhaul Procedure."
D. Hand cranking difficult.	(1) Misalignment of cranking extension.	(1) Re-align and install as instructed under "Installation."
	(2) Crank-extension bearing not lubricated.	(2) Lubricate as instructed under "Lubrication."
	(3) Improper starter lubrication.	(3) Disassemble and lubricate as instructed under "Lubrication" and "Major Overhaul Procedure."
	(4) Engine-oil leakage into starter.	(4) Disassemble, clean, lubricate, and replace worn oil seals as instructed under "Service Inspection and Maintenance" and "Major Overhaul Procedure."
	(5) Barrel adjusting nut adjusted too tight.	(5) Adjust as instructed under "Major Overhaul Procedure."
	(6) Ball bearings worn or rough turning.	(6) Disassemble as instructed under "Major Overhaul Procedure."

EQUIPMENT TROUBLES AND REMEDIES—*continued.*

Trouble	*Possible Cause*	*Remedy*
E. Fluctuation in clutch setting with gradual increasing value.	(1) Worn or scored clutch discs.	(1) Replace and test as instructed under "Major Overhaul Procedure" and "Final Assembly and Test."
	(2) Clutch not properly set.	(2) See "Clutch Adjusting and Test" and "Final Assembly and Test."
F. Motor fails to operate or operates at too low speed.	(1) Wiring not properly connected.	(1) See wiring diagram (Fig. 3).
	(2) Loose or high resistance connections.	(2) Clean and tighten.
	(3) Loose or corroded battery terminals.	(3) Clean and tighten.
	(4) Low voltage input.	(4) Check and recharge battery.
	(5) Brushes binding.	(5) Remove and wipe clean with a benzine-moistened cloth.
	(6) Worn brushes.	(6) Replace as instructed under "Service Instructions and Maintenance" and "Major Overhaul Procedure."
	(7) Brushes not properly seated.	(7) Reseat as instructed under "Service Instructions and Maintenance" and "Major Overhaul Procedure."
	(8) Excessive brush side play	(8) Replace as instructed under "Service Instructions and Maintenance."
	(9) Dirty commutator.	(9) Clean and smooth as instructed under "Service Instructions and Maintenance."
	(10) Rough or pitted commutator.	(10) Disassemble and proceed as instructed under "Major Overhaul Procedure."
	(11) Shorted, earthed, or open-circuited armature.	(11) Disassemble and test as instructed under "Major Overhaul Procedure."
	(12) Brush spring tension low.	(12) Test as outlined in "Major Overhaul Procedure."
	(13) Earthed or open-circuited field coil.	(13) Disassemble and test as instructed under "Major Overhaul Procedure."
	(14) Solenoid starting-switch coil earthed or open circuited.	(14) Test as instructed under "Major Overhaul Procedure."
	(15) Accelerating switch contacts dirty or pitted.	(15) Clean or replace contacts.
	(16) Solenoid contacts sticking.	(16) Disassemble and clean.
	(17) Push-pull switch inoperative.	(17) Test as instructed under "Major Overhaul Procedure."

EQUIPMENT TROUBLES AND REMEDIES—*continued.*

Trouble	*Possible Cause*	*Remedy*
G. Excessive arcing of motor brushes.	(1) Same as under "F," Items 5–12.	(1) Same as under "F," Items 5–12.
H. Booster coil fails to operate.	(1) Rough or pitted contacts.	(1) Smooth or replace as instructed under "Major Overhaul Procedure."
	(2) Contacts not set correctly.	(2) Reset as instructed under "Major Overhaul Procedure."
	(3) Condenser broken down.	(3) Replace condenser.
	(4) Loose or broken connections.	(4) Check wiring.
	(5) High tension lead earthed.	(5) Examine lead and insulating bushing for signs of arcing.
	(6) Coil burnt out.	(6) Replace coil.

LUBRICATION

All starters are sufficiently lubricated at the factory, and should require no further lubrication between major engine-overhaul periods. However, after every 50 hours of operation, the crank-extension support bearing should be lubricated with engine oil. The following lubricants should be used at major overhaul periods to assure satisfactory operation :

Part	*Lubricant*	*Manufactured by*
Ball bearings	N.E. grease	Edgar Vaughan & Co., Ltd., Birmingham.
All gears Plain bearings Clutch discs	Gredag Grease No. 223	E. G. Acheson, Ltd., Thames House, Millbank, London, S.W.1.

These lubricants may be obtained from Rotax Limited, or one of its authorised service stations, in various-sized containers.

Caution.—The use of lubricants other than those specified will result in inferior starter performance or damage to starter.

SERVICE INSPECTION AND MAINTENANCE

A. Service Inspection (50 hours)

The starter, when properly installed and operated, should not require attention between major overhaul periods. However, it is recommended that after every 50 hours of engine operation, the crank-extension support bearing be lubricated as instructed under "Lubrication."

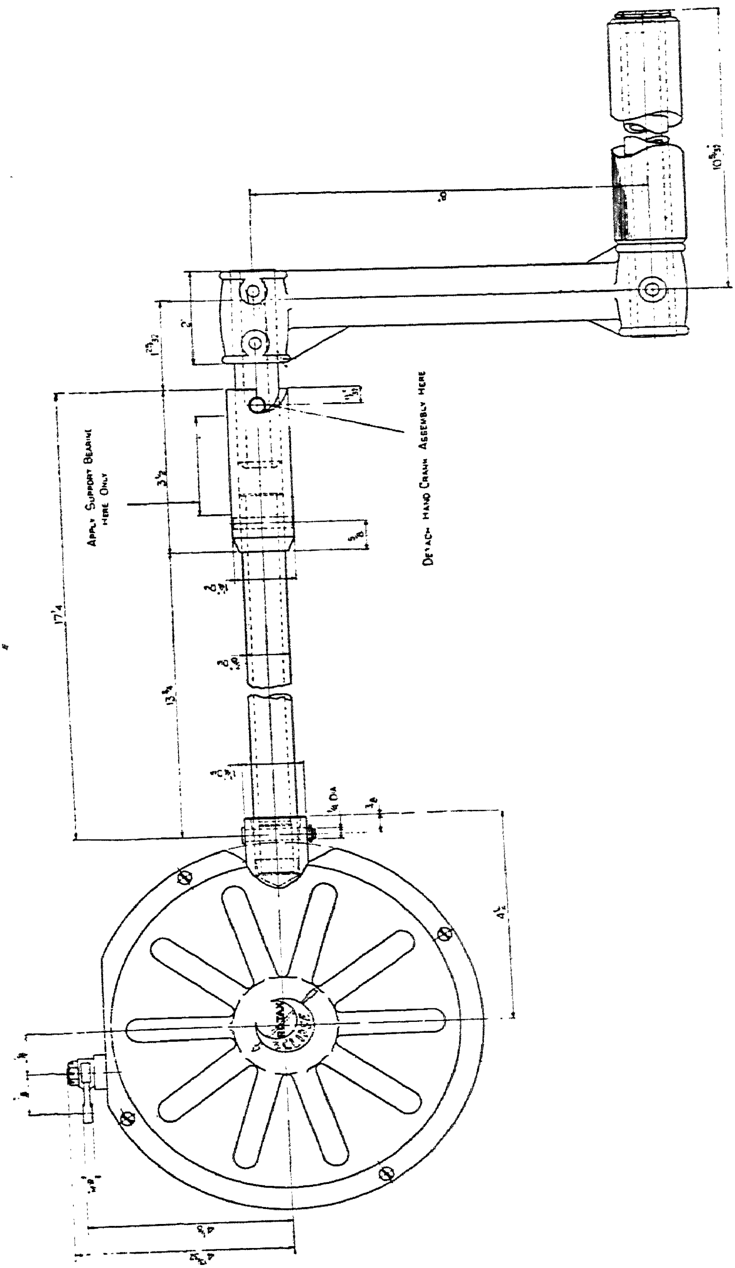

Fig. 5.—Hand crank and extension assembly

B. Service Inspection (100 Hours)

In addition to the procedure outlined for 50-hour inspection, it is recommended that after every 100 hours of engine operation the window strap on the motor of electric starter be removed and inspected for :

(1) Accelerating Motor

(*a*) *Loose Connections*

(*b*) *Worn or Binding Brushes*

When replacing a worn brush, it is necessary to bed the brush properly by inserting a strip of fine carborundum cloth between the brush and commutator, with rough side next to the brush and pull in the direction of rotation. The operation should be repeated until the brush is completely bedded. Binding brushes and brush boxes should be wiped clean with a benzine-moistened cloth. Worn brushes should be replaced immediately, as burning of the commutator and insulation usually results from failure to make such replacement in time. The maximum permissible wear of brushes is $\frac{3}{16}$ in. from a new length of $\frac{1}{2}$ in.

Caution.—Do not use coarse sandpaper or emery cloth. Remove dust or metal particles with compressed air.

(*c*) *Rough or Dirty Commutator*

If the commutator is rough or dirty, smooth with fine carborundum cloth. For badly scored commutator, see "Major Overhaul Procedure."

(*d*) *Oil Leakage*

Excessive oil in starter-gear case and around the flywheel will result in failure to energise the starter. This condition may be readily determined by removing the flywheel cover of hand inertia starters or by removing the motor in the case of electric inertia starters. Oil leakage may be due to worn baffle plate or meshing-rod oil seals or to improper adjustment of the control linkage. If excessive oil is present in the starter, the unit must be completely disassembled as outlined in "Major Overhaul Procedure."

(2) Solenoid Switch

Should the motor of electric inertia starters equipped with a solenoid starting switch be inoperative, connect a jumper cable across the large terminals of the solenoid switch. If the motor then operates, the solenoid or push-pull switch is inoperative, and replacement should be made.

MAJOR OVERHAUL PROCEDURE

Remove the starter from the engine, and disassemble at every major engine overhaul. Before removing the starter from the engine, disassemble the crank extension by removing the pin in the drive end of the extension assembly. Disconnect the pull rod or cable from the bell

crank of hand inertia starters, and detach from the starter. If the starter is of the electric type, disconnect all external wiring before detaching the starter. Detach the accessory units from the starter and disassemble. The motor of electric inertia starters may be separated from the starter by removing the four flange bolts. For further overhaul procedure, consult the cross-sectional drawings of the various units and proceed as follows:

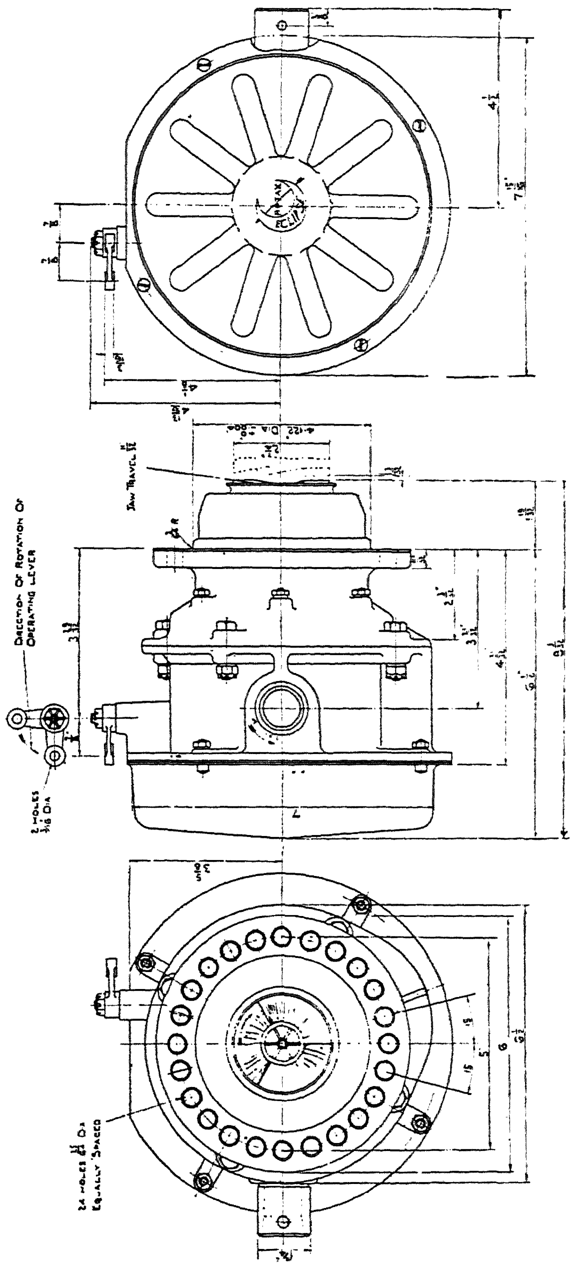

Fig. 6.—Outline of Rotax-Eclipse Series XI Inertia Starter

A. Starter Overhaul

(1) Starter Disassembly

After detaching the motor, or, in the case of hand inertia starters, the flywheel cover, remove in succession from the starter-drive end the meshing-rod nut, jaw, baffle plate assembly, sleeve, lock ring, leather washer, steel backing washer, and meshing-rod spring. If disassembly of the clutch is contemplated, remove the

clutch adjusting-nut lock, and loosen the nut before disassembling the flywheel.

Caution.—Disassembly of the starter clutch is recommended at every major overhaul to assure proper lubrication of the clutch discs. It is particularly important that the clutch be disassembled if the presence of engine oil in the starter housing is noted. If suitable test equipment is not available, as outlined under "Final Assembly and Test," and starter operation has been satisfactory prior to overhaul, the starter clutch should not be disassembled.

Before disassembling the clutch, note the distance that the barrel projects over the clutch adjusting nut.

To remove the clutch barrel assembly with planetary gears attached from the clutch housing, separate the starter by removing the bolts securing the clutch housing to the gear housing. Remove in succession from the crank end of the barrel assembly the barrel shaft nut, nut lock, bevel-drive pinion, thrust washer, and sun gear. With the barrel assembly in the vertical position and the mounting flange upward, remove the lock ring, external barrel adjusting nut, ballrace, and balls. Invert the barrel and housing assembly, and remove the clutch barrel assembly with planetary pinions attached. Remove carefully to avoid losing the balls in the rear race.

The planetary pinions may be separated from the driving barrel by detaching the planetary pinion studs and removing the planetary ring. Do not remove the annulus gear unless replacement is to be made.

To disassemble the clutch, remove successively the clutch adjusting nut, spring ring, springs, spring spacer, spline-nut assembly, spline-nut bushing, clutch discs, and spacer. Fasten clutch discs together to retain their relative order.

In order to disassemble the flywheel pinion, it is necessary to remove the clevis and crankshaft bevel gear to provide sufficient clearance for removal of the bell gear. To disassemble the flywheel pinion, remove in succession the clevis-shaft nut, clevis, spring, clevis shaft, with bell crank attached, crankshaft nut, bevel-drive pinion, crankshaft, flywheel nut, flywheel, bell-gear nut, and bell gear. To remove the flywheel, which is keyed to the flywheel pinion, exert pressure equally at opposite points on the flywheel rim. The flywheel and bell-gear ball bearings may then be removed from the housing.

(2) Starter Inspection

Thoroughly clean and examine all parts. Examine for wear, and lubricate.

(*a*) *Ball and Roller Bearings.*—Replace all ball and roller bearings if rough turning or excessively loose radially.

(*b*) *Clutch Barrel Assembly.*—Wipe the exterior with a benzine-moistened cloth. *Do not immerse in benzine.*

Note.—If the clutch has been disassembled, replace all worn parts, and lubricate. All worn or scored clutch discs should be replaced. Procedure for clutch setting is outlined under "Clutch Adjusting and Test," in "Final Assembly and Test."

(*c*) *Baffle-plate Assembly.*—If oil-seal leathers are worn or torn to the extent that they are a clearance fit on the outside diameter of the starter jaw, or if they are wrinkled to the extent that the starter jaw does not form a tight seal against the leather when fully retracted, the baffle-plate assembly should be replaced. The presence of engine oil in the starter housing indicates a worn baffle-plate oil seal, and replacement should be made.

The baffle-plate assembly has been redesigned to incorporate a cup type of oil-seal leather, thereby providing a better oil seal. When replacement of the baffle-plate oil-seal leather is desired, a complete unit should be substituted. Do not break down the assembled unit under any conditions. When installing the improved baffle-plate assembly, a redesigned cup-type starter-jaw oil-seal sleeve must be utilised.

Note.—New baffle-plate assemblies should be soaked in "Neats-foot" oil at 100° *F. for a period of one hour prior to assembly, to ensure free travel of the starter jaw in the baffle-plate assembly.*

(*d*) *Meshing-rod Leather.*—Replace the meshing-rod leather oil seal at every overhaul.

(*e*) *Screw-shaft Assembly.*—Replace the screw-shaft assembly when the screw-shaft threads become rough, or at such time as the starter-jaw splines come in contact with the screw-shaft threads.

(*f*) *Bell Gear and Flywheel-bearing Spacers.*—Replace bell gear and flywheel-bearing spacers if worn to the extent that they no longer clamp the inner race of the ball bearings when assembled in place.

(*g*) *Ball Rings and Races.*—Replace ball rings or races when excessively pitted or scored.

(*h*) *Starter Jaws.*—Replace the starter jaw if worn to the extent that the amount of flat remaining on the leading edge or face of the starter jaw is less than $\frac{5}{32}$ in.

(*j*) *Planetary Ring and Sun-gear Assembly.*—Replace the sun-gear assembly when the bronze bushing is worn to the extent that the total deflection, as measured at the rim of the gear while in place, exceeds $\frac{1}{32}$ in., which is equivalent to approximately 0·008-in. wear in the diameter of the bushing.

Caution.—Sun-gear assemblies of Series XI starters have been redesigned for use in conjunction with a bronze planetary ring of new design, which serves as a bearing plate to prevent tilting of the sun gear as the bushing wears. In some starters, however, a separate bronze bearing plate, mounted on the planetary ring, is utilised. Starters in which the bearing-plate type of construction is incorporated, embody a sun gear which is interchangeable with the present-production sun gear. However,

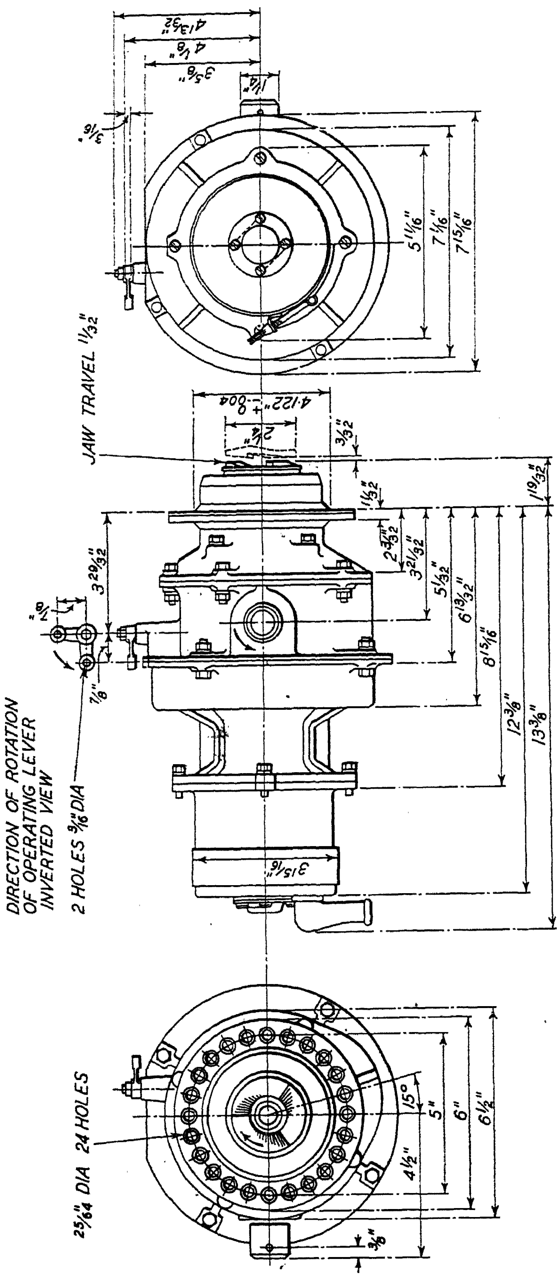

Fig. 7.—Outline of Rotax-Eclipse Series XI electric and hand inertia starter

when replacing sun gears in earlier-model starters in which a plain type of planetary ring is utilised, replacement of the old planetary ring with one of the latest design is required when replacing the sun gear. Sun-gear assemblies may be sent to the factory for rebushing, providing that both the internal and spur gears are in good condition.

(*k*) *Meshing-rod Nuts.*—The dural meshing-rod nut, which retracts the starter jaw, has been changed to steel for increased strength. The material was changed to steel to eliminate the possibility of stripping the threads and shearing off the cotter pin, thereby allowing the nut to drop into the engine crankcase. Replace dural nuts with steel nuts at overhaul.

(3) Starter Assembly

To assemble the starter, follow the disassembly procedure in the reverse order. Parts should be lubricated. Re-

place all locking devices and safety wire. In addition the following precautions should be observed :

(*a*) *Ballraces.*—In order to facilitate assembly of the driving barrel in the front housing, coat the ballraces with grease, Grade N.E., to hold the balls in place. Sixty balls are required for each race of Series XI starters.

(*b*) *Planetary Pinions.*—Attention is invited to the fact that it is not necessary to assemble the planetary pinions in any specific position.

(*c*) *Barrel Adjusting Nut.*—Be sure that the barrel adjusting nut has been taken up, so that no appreciable end or side play exists when the barrel is assembled in the front housing. To ensure proper adjustment of the barrel adjusting nut, tighten until snug, and then back off one full hole. The clearance between the adjusting nut and the ballrace should be at least 0·003 in. No binding should exist, or free-running time will be affected. After completing adjustments, assemble the barrel adjusting-nut lock ring in place.

(*d*) *Clutch Assembly.*—Lubricate and replace clutch discs in the same relative positions as before disassembly. Tighten adjusting nut so that the barrel extends over the nut the same distance as noted before disassembly. If worn or scored discs have been replaced, the clutch adjusting nut should be assembled $\frac{1}{16}$ in. below the end of the clutch barrel. Too low an adjustment of the clutch setting prior to testing will result in burning of the clutch plates. Procedure for final clutch setting is outlined in " Final Assembly and Test."

Note.—If worn or scored discs have been replaced, or an entirely new clutch pack installed, it is recommended that the clutch be alternately slipped at 6·5 r.p.m., using a 110-volt motor drive, and cooled for periods of 5 minutes. Repeat the above procedure until 320 revolutions of slipping have been obtained and assemble clutch in starter. The above method of running in new clutch discs will aid materially in obtaining final clutch adjustment.

(*e*) *Meshing-rod Lock Ring.*—Be sure the meshing-rod lock ring is assembled in place before assembling the meshing-rod nut. Tighten the meshing-rod nut until snug. Too tight an adjustment of the meshing-rod nut will force the lock ring out of its groove.

(*f*) *Bell-gear Spacer.*—Assemble bell-gear spacer with counter-bored end adjacent to bell gear.

(*g*) *Starter Jaw.*—When assembling starter jaw in baffle-plate oil seal, care must be taken to prevent scoring of the oil-seal leather.

B. Motor Overhaul

(1) Motor Disassembly

Disassembly of the motor is readily determined from the cross-section drawing. Do not disassemble pole shoes or field coils from the yoke

unless replacement is contemplated. Before disassembling the field coils, note position of the leads.

(2) Motor Inspection

Thoroughly clean and examine all parts. Check for wear, and lubricate.

(*a*) *Commutator.*—To remove dirt or grease from the commutator, wipe clean with a benzine-moistened cloth, and smooth with fine carborundum cloth. *Do not use coarse sandpaper or emery cloth.* Thoroughly clean armature before assembly, to remove all dust.

If the commutator is extremely rough or burned, mount armature in lathe and take a light cut across the face of the commutator, using a sharp-pointed lathe tool and a cutting speed of approximately 200 surface feet per minute. The minimum diameter to which a commutator may be turned is 1·375 in. After turning, carefully undercut the mica insulation between the commutator bars to a depth equal to the width of the mica or 0·030 in. A cutting tool slightly wider than the mica should be used to ensure complete removal of the mica to the required depth. Smooth and polish the commutator with fine carborundum cloth at approximately 700 surface feet per minute, after undercutting to remove any burrs. Thoroughly clean armature before assembly to remove all metal dust. Do not use oil on the commutator at any time.

(*b*) *Brush Springs.*—Check brush spring for required tension before assembling starter. Should the tension be less than 36 oz. when compressed to a length of $\frac{7}{16}$ in., replacement should be made.

(*c*) *Brushes.*—The maximum permissible wear of brushes is $\frac{3}{16}$ in. from a new length of $\frac{1}{2}$ in. However, brushes should be replaced at overhaul unless there is sufficient wear to permit satisfactory operation until the next inspection.

(*d*) *Motor Stop Nuts.*—The motor jaw stop nut is slotted to permit locking. Care should be taken, when removing or assembling the stop nut, to avoid distortion of the threaded prongs with resultant damage to the threads. On no occasion should the nut be removed by tapping the slotted part in close to the thread.

(*e*) *Motor-jaw Spring.*—Close inspection should be made at the time of overhaul, prior to assembly, that a spring of proper rotation is installed. Installation of a motor-jaw spring of the wrong rotation will result in distortion of the spring.

(*f*) *Motor Jaws.*—The motor jaw should fit freely on the armature shaft and be lubricated with Gredag No. 322 grease to ensure free travel. Replacement of the motor jaw or armature shaft, due to the wear of the screw shaft splined, is seldom necessary, as close limits at this point are not required. However, if the splines should become chipped or rough to the extent that the jaw does not move freely, replacement of the jaw or armature, as the case may be, is recommended.

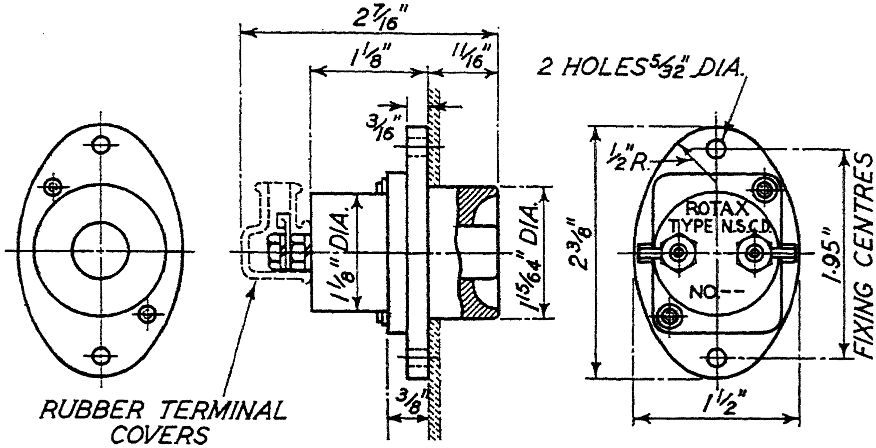

Fig. 8.—Outline of starter push switch

(*g*) *Back-head Motor Ball Bearings.*—The back-head ball bearings of Type Y-100 starter motors are staked in place to eliminate interference of the ball bearing with the demeshing of the motor jaw, should movement of the ball bearing on the shaft occur. The bearing is staked in three places by driving a sharp tool into the back head about $\frac{1}{16}$ in. from the ballrace and cramping the steel against the race. When replacing the ball bearing, it should be removed from the inside of the head, so that the staking is not altered.

(*h*) *Field-post Insulators.*—Inspect field-post insulators for cracks, and replace if necessary.

(*i*) *Pole-shoe Screws.*—Rigid inspection at each overhaul should be made to determine if the pole-shoe screws are tight. A special screw-driver press is recommended for use in tightening the pole-shoe screws. If for any reason it has been necessary to remove the pole shoes from the yoke, a pole-shoe expander should be used in order properly to align the pole shoes.

(3) Test at Inspection

Test the armature and field coils for shorts, earths, and open circuits before assembling. (*Note.*—When testing with a lamp circuit, a 220-volt line is recommended.) Replace shorted, earthed, or open-circuited field coils and armatures.

(*a*) *Shorted Armature.*—To test for a shorted armature, a " growler " should be used. If a growler is not available, examine commutator to make certain no two adjacent bars are joined electrically by foreign matter, such as copper chips, solder or carbon dust. If armature windings appear to be burnt, indicating weakened insulation, the armature should be replaced.

(*b*) *Earthed Armature.*—To test for an earthed armature, connect one side of the "Megger" circuit to the armature shaft, and connect the other terminal to the commutator bars. If the armature is earthed, the Megger reading will clearly indicate the fact.

(*c*) *Open Circuits.*—Inspect the commutator for black or burnt commutator bars, and be sure that all conductors are firmly soldered into the riser. Loose conductors or blackened commutator bars indicate the possibility of an open circuit.

(*d*) *Open Field Circuit.*—To test for an open field circuit, connect the two terminals of a 220-volt lamp circuit to the two field-coil terminals. The lamp will light if there is no open circuit.

(*e*) *Earthed Field Circuit.*—To test for an earthed field circuit, connect one side of the "Megger" to one of the field terminals, the other field terminal being free. Touch the other lead of the "Megger" to the yoke momentarily.

(4) Motor Assembly

To assemble the motor, follow the disassembly procedure in the reverse order. Parts should be lubricated. Replace all locking devices and safety wire.

(*a*) *Motor Field Leads.*—Field leads should be connected in the same position as noted before disassembly.

(*b*) *Motor Brushes.*—The brushes should be a free fit without excessive side play in the brush boxes.

To ensure proper seating of new brushes, place a thin strip of fine carborundum cloth under the brushes at assembly, with rough side in contact with the brush surface. Turn armature in the *proper direction of rotation*, until the brushes are completely seated. Remove all dust or metal particles with compressed air.

Note.—If the brush rigging has been removed from the motor, a rectangular bar corresponding in size to the brush box should be replaced through the brush boxes, prior to tightening the brush-box screws. By this means, perfect alignment can be obtained before tightening the screws. This method of aligning the brush boxes will materially improve commutation.

(*c*) *Motor Jaw.*—The motor jaw and spring should be of the correct rotation for the motor being installed. Be sure the jaw is well lubricated and free to slide on the armature shaft.

(5) Motor Test at Assembly

After assembly and before attaching to a starter, the motor should be tested by applying 6 or 12 volts for 12- and 24-volt motors respectively to the motor terminals. The motor speed should be at least 9,000 r.p.m., with a maximum current draw of 65 and 25 amperes for 12- and 24-volt motors respectively. Do not run a 12- or 24-volt motor free at its rated voltage, as excessive speed will result.

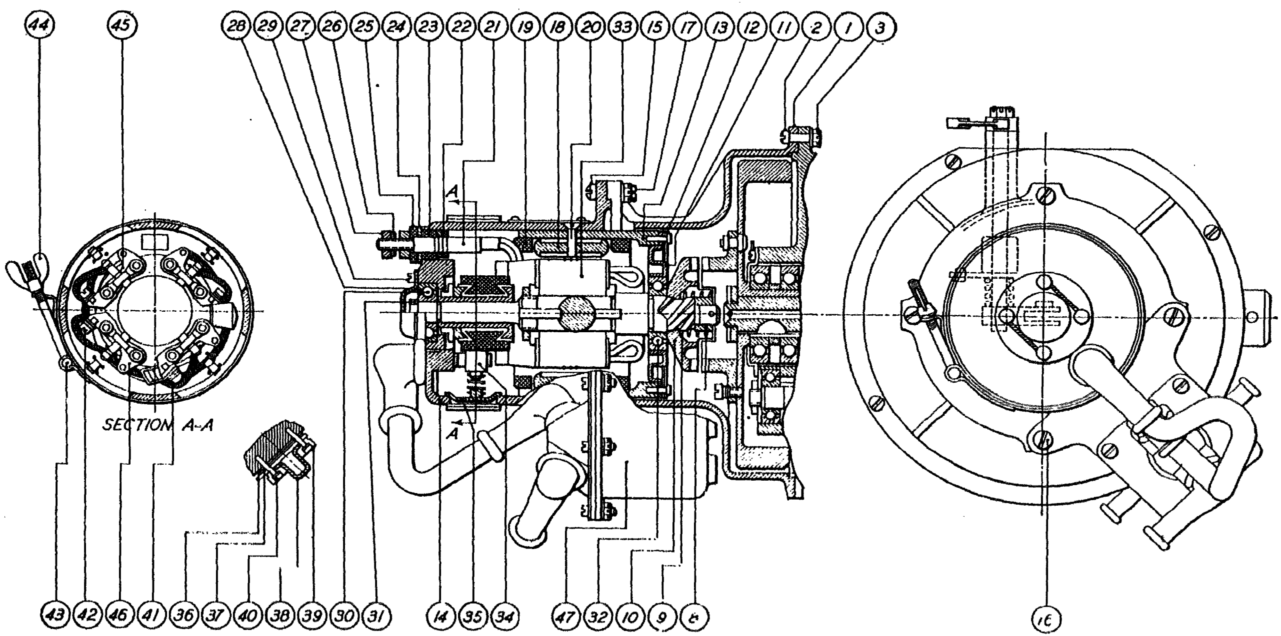

Fig. 9.—Accelerating motor adapted to Series XI inertia starter

1, Motor bracket ; 2, motor-bracket screw ; 3, nut for item 2 ; 4, flywheel ; 5, dog assembly ; 6, dog screw (fixing) ; 7, lock pin ; 8, stop nut ; 9, motor-jaw spring ; 10, motor jaw ; 11, back head ; 12, back-head screw ; 13, yoke ; 14, motor housing ; 15, motor-housing screw ; 16, screw for motor housing and switch bracket ; 17, nut for items 14 and 15 ; 18, pole-shoe assembly ; 19, field-coil assembly ; 20, screw for item 18 ; 21, field post ; 22, insulator ; 23, bushing ; 24, washer for terminals ; 25, spacer for terminals ; 26, lock washer ; 27, terminal nut ; 28, front-bearing cap ; 29, screw for item 28 ; 30, ball bearing (commutator end) ; 31, nut for item 30 ; 32, ball bearing (drive end) ; 33, armature assembly ; 34, brush assembly ; 35, brush-spring assembly ; 36, brush-bracket insulator (rectangular) ; 37, brush-bracket insulator ; 38, brush box ; 39, brush-box screw insulator ; 40, brush-box screw ; 41, terminal screw ; 42, terminal screw ; 43, window-strap assembly ; 44, wing nut for item 43 ; 45, brush rest ; 46, brush rest ; 47, solenoid switch complete.

After assembly, the motor should be given an insulation test on the "Megger."

After completing the above tests for 12- and 24-volt motors respectively, open and close the operating switch several times to see if the automatic engaging mechanism operates freely.

D. Booster-coil Overhaul

(1) Booster-coil Disassembly

The booster coil should be sufficiently disassembled to permit cleaning or resetting of the contacts. To clean or reset booster-coil contacts, remove the four housing screws and cover, and proceed as outlined under "Inspection." No further disassembly of the booster coil is required unless replacement of parts is contemplated.

(2) Booster-coil Inspection

Clean dirty booster-coil contacts by inserting a piece of clean paper between them, pressing the contacts together and pulling out the paper. However, if the contacts are slightly pitted, their faces should first be cleaned off by the use of very fine carborundum cloth and then cleaned with paper. Badly pitted or burnt contacts should be replaced. *Do not use emery cloth.*

After cleaning the contacts, the gap should be adjusted by means of the ratchet screw on the stationary contact, so that the current through the primary coil, when the booster coil is operating, is 1·8 or 1·5 amperes for 12- and 24-volt coils respectively, and the booster coil is firing a 9-kilovolt gap at atmospheric pressure.

(3) Booster-coil Assembly

After cleaning or setting the contacts, assemble the booster coil. Replace all locking devices and safety wire.

E. Solenoid Switches

(1) Disassembly

Disassembly of starter switches is not recommended unless replacement of parts is contemplated. Disassembly procedure may be readily determined from the cross-sectional drawings of the unit.

(2) Inspection of Control Devices

(*a*) *Earthed Coil Circuit.*—To test a solenoid switch for an earthed coil, connect one terminal of a "Megger" to one of the coil terminals. Touch the other terminal to the coil housing; the reading should be about 2 megohms.

(*b*) *Open-circuited Coil.*—To test a solenoid switch for an open circuit,

connect the two terminals of a lamp circuit to the two coil terminals. The lamp will light if there is no open circuit.

(3) Test at Assembly

(*a*) *Solenoid Switches.*—Check solenoid switches at two-thirds rated voltage for proper operation.

(*b*) *Single-contact Push-pull Switch.*—To test the single-contact push-pull switch, connect the two leads of a lamp circuit to the two switch terminals. If the lamp lights with the switch in the closed position, the switch contacts are satisfactory.

FINAL ASSEMBLY AND TEST

Assemble the accessory units to the starter, and proceed as follows :

A. Starter-jaw Travel

With the jaw completely retracted, the travel to full advanced position should be $\frac{11}{32}$ in.

B. Clutch Adjusting and Test

A prony brake and scale test stand is recommended for clutch testing.

(1) If clutch discs have not been disturbed or adjusted during overhaul, the clutch setting can be checked as follows :

Mount the starter on the clutch adjusting stand with baffle-plate removed. Adjust the mounting bracket so that the distance between the starter jaw and engine jaw is $\frac{3}{32}$ in. when the starter jaw is fully retracted. Lock brake drum of test stand. Accelerate the flywheel of starter either manually or electrically to a speed of 10,500 r.p.m. After accelerating the flywheel to the required speed, mesh the starter jaw with the test stand jaw, and repeat the procedure five consecutive times at one-minute intervals. If the clutch setting remains constant at the value shown in the following chart, it can be considered satisfactory. To lower the setting, screw the clutch adjusting nut outward; to raise, screw inward. After the correct setting has been reached, engage at least five consecutive times at one-minute intervals to determine if setting remains constant.

CAUTION.—*Do not operate motor with bearing retainer removed unless outer race is clamped by the two large washers. A cut-away bearing cap may be used for this purpose. Be sure the clutch adjusting-nut lock is in place before assembling the baffle plate.*

Clutch should be set in accordance with the following chart :

Type	*Final Clutch Setting*	*Minimum Free Run-down time from* 12,000 *r.p.m.*
Series XI.	650 lbs./ft., plus or minus 20 lbs./ft.	4½ minutes.

(2) If the clutch has been disassembled and worn discs replaced, the final setting must be approached gradually. Accelerate and engage the starter until the clutch maintains a constant torque value of at least 200 lbs./ft., being careful not to overheat the clutch. Then gradually increase clutch value, accelerating and engaging the starter between each increase in clutch setting, until the required setting is obtained. When final setting is reached, allow starter to cool to room temperature, and give five consecutive engagements at one-minute intervals. If setting remains constant, the clutch has been properly adjusted.

The general procedure in clutch adjusting and testing should be to attain gradually the required setting without overheating. It is very important that no other grease, except that specified under "Lubrication," be used.

The lubricant has been selected as the result of exhaustive tests, and its use is necessary to successful operation.

C. Test for Free Running

Following the clutch setting, assemble the clutch adjusting-nut lock and baffle-plate, and check for free running. Accelerate the flywheel to a speed of 12,000 r.p.m., either manually or electrically, and record the time required to come to stop while free running. The minimum run-down time should be within the limits prescribed in the above chart, after no more than two trials. If the run-down time is low, disassemble the starter and remove the stiffness.

D. Manual Acceleration

After completing the above tests, the starter should be manually accelerated to ensure proper operation of cranking gears and ease of acceleration.

E. Accessories

If starter equipped with electric motor, booster coil, solenoid switch, or any combination of the aforementioned accessories, each of such items should also be checked for proper operation. All electrically operated accessories should perform at two-thirds of their rated voltage.

The preceding notes on the operation and maintenance of electric starters and generators are based on information supplied by Messrs. Rotax Ltd. We take this opportunity of expressing our indebtedness to this firm for their courteous co-operation in enabling us to publish these details.

THE MAINTENANCE OF ELECTRIC STARTING SYSTEMS

WITH PARTICULAR REFERENCE TO B.T.H. AND ARMSTRONG SIDDELEY STARTERS

THE electric starting of small aeroplane engines does not differ materially in principle from the starting of automobile engines. A motor, supplied from a 12- or 24-volt battery, turns the engine through reduction gearing, with means for automatically connecting and disconnecting the drive to the engine. This may be supplemented by an impulse starter incorporated in the magneto drive to give an intense spark for starting.

The starter itself is, however, different, as the aeroplane engine has no flywheel to which a motor can be geared (the airscrew providing sufficient flywheel effect), and the starter is normally applied to the rear end of the engine crankshaft, and contains the necessary reduction gearing and engagement mechanism.

Large Engines

It is not practicable, however, to turn any but small engines fast enough to obtain ignition from the main magnetos, as the power required, even with the aid of an impulse starter, would demand a motor, battery, and cables of prohibitive weight.

For example, consider what it would mean to turn an engine of 1,000 h.p. at 100 r.p.m. Under conditions of extreme cold it may be taken that such an engine would require at least 500 lbs./ft. torque to turn it.

$$\text{Since horse-power} = \frac{2\pi}{33{,}000} \times \text{r.p.m.} \times \text{torque}$$

$$\therefore \text{horse-power} = \frac{2\pi}{33{,}000} \times 100 \times 500 = 9{\cdot}5.$$

Allowing an efficiency of, say, 75 per cent. for the gearing, the required horse-power of the motor would be $\frac{9{\cdot}5}{75} \times 100 = 12{\cdot}6$ h.p. approximately. This would be quite a large motor, and would weigh probably 40 lb., apart from the gearing.

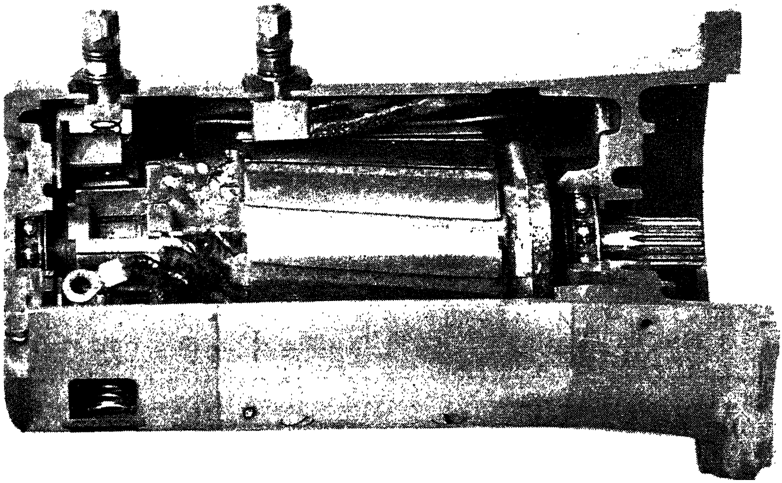

Fig. 1.—Sectional view of B.T.H. starter motor type C.A. 4125

Current

Consider too the current which such a motor would require. Assuming the efficiency of such a motor to be 70 per cent. its input would be :

$$\frac{12{\cdot}6}{70} \times 100 \times 746 \text{ watts} = 13{,}430 \text{ watts.}$$

On a 12-volt system, due to the drop in battery and cables, one could not expect more than 8 volts at the motor terminals. The current consumption would therefore be 13,430 $\div$ 8 = 1,678 amps. This current would, of course, be halved for a 24-volt system. It will be readily appreciated that the size and weight of cables and batteries to deal with these currents would be excessive, to say the least.

Low Cranking Speed

Since horse-power is proportional to speed, it is obvious that the way to reduce the size of the starting equipment is to reduce the cranking speed. It is now usual practice to turn the engine at speeds of about 12 to 30 r.p.m., the engine being primed, and to obtain ignition by means of a trembler coil or hand-turning magneto, which provides a stream of sparks fed into the engine through the distributors of the main magnetos which correctly time them.

Ground Battery for Starting

Even so, the current consumption would be a severe strain on the battery normally carried for other services, or would demand the carrying

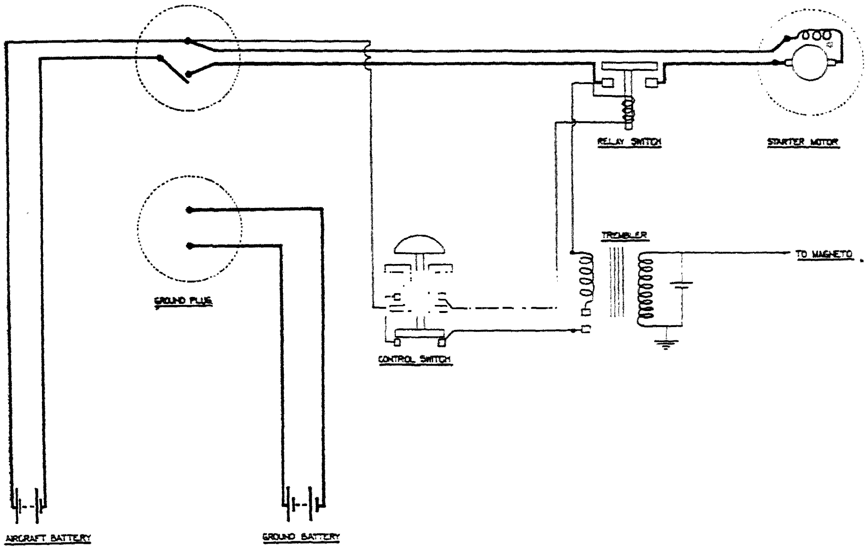

Fig. 2.—CONNECTION DIAGRAM FOR STARTER CIRCUIT USING A RELAY SWITCH

of a larger battery than the other services warrant, and it is now usual practice to carry in the aeroplane a battery of sufficient capacity to deal with other services and just to start the engine in emergency, and for everyday use to employ a ground battery for starting.

A battery of relatively large capacity is carried on a ground trolley, and plugged into the aeroplane for starting. This not only reduces the weight of the equipment carried, but ensures that the aeroplane battery is not drained by starting the engines.

Special Plugs and Sockets

When using the ground battery it is desirable to isolate the aeroplane battery from the starting circuit, and this is accomplished by using a special socket on the aeroplane for receiving the plug from the ground battery. This socket has a moulded cover, which in its normal position masks the socket holes. It contains two holes with which the pins of the plug engage, and when rotated to the operating position the pins of the plug can be pushed into the socket, making contact therewith. The cover in rotating is made to open a switch isolating the aeroplane battery. When the plug is removed, the cover, being spring-loaded, returns to its normal position, reconnecting the aeroplane battery.

Solenoid or Relay Switch

In order further to reduce weights, a solenoid or relay switch is usually employed. This avoids running heavy cables into the cockpit, the heavy

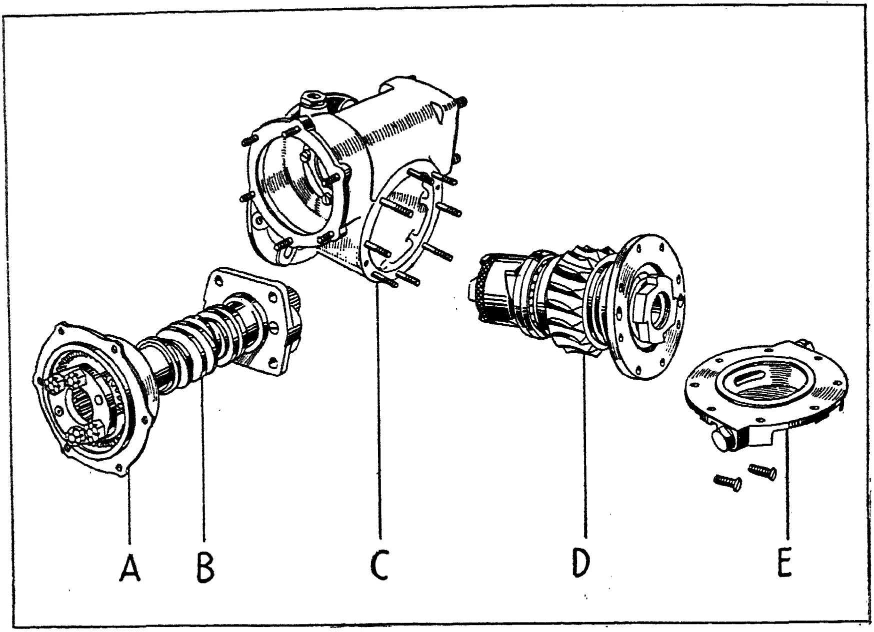

Fig. 3.—Armstrong Siddeley gear-box to which motor shown in Fig. 1 is applied

cables taking the shortest practicable path between battery, starter, and ground socket. The switch is operated by a solenoid which, taking only about 50 watts, requires the running of only light leads to a small control switch mounted in the cockpit. This control switch frequently has contacts to control the trembler coil, when one is used, and provides for the operation of the coil and starter together for normal operation, the starter only (for turning the engine for engine adjustments) or the coil only (for hand starting).

A connection diagram for such a system is shown in Fig. 2. Fig. 1 shows a starter motor partly sectioned. Fig. 3 shows an Armstrong Siddeley gear-box to which the motor in Fig. 1 is applied. Fig. 4 shows a solenoid switch and its double-knob control switch (for use with trembler coil). Fig. 5 shows a ground plug and socket.

Inertia Starters

Although it has been stated above that the rotation of the engine quickly involves large power, this is not strictly true, as the inertia type of starter does not require excessive current. Whilst the inertia starter is not so widely used as the turning gear, a number are in use, and its underlying principles are worthy of attention.

Fig. 4.—External view of solenoid switch, type 0–4B1 and switch type N

Principle of Operation

The fundamental principle of operation is that of first storing up energy in a small flywheel by rotating it electrically at high speed (usually about 16,000 r.p.m.), and then applying this energy to the crankshaft of the engine to be started through the medium of a reduction-gear train incorporating a torque overload release or clutch. This principle permits energy to be drawn from a battery at a very low rate, so that it is only necessary to use a comparatively small battery and small-diameter cables. The energy stored in the flywheel is applied to the engine at a high rate, causing the engine to be rotated quickly—the ideal condition for certain starting.

Slipping Clutch

In normal inertia starters, the starter driving dog rotates at approximately 80 to 100 r.p.m. prior to engagement with the engine dog, which is

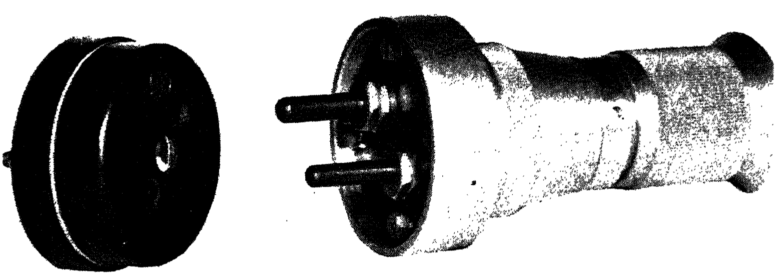

Fig. 5.—External view of ground plug type EP–1 and ground socket type E–1

stationary. Since the engine and airscrew have inertia and therefore cannot attain the speed of the starter immediately without the application of an enormous torque which would damage the engine crankshaft, a slipping clutch is incorporated between the starter dog and the flywheel, which relieves the shock of engagement, and limits to a predetermined value the torque which the starter can apply to the engine crankshaft.

A certain amount of energy must be lost in the clutch at engagement, and the correct value of the clutch setting is important, because if the clutch is set too low, more energy will be lost than is necessary, and if set too high, damage to the engine or the starter may result.

It should be noted that the inertia starter takes much less current than a starter which turns the engine directly, but that is not to say that it takes less energy. Whatever the starter, it has a certain amount of work to do, to apply a torque for a given number of revolutions, and the energy that this represents plus the losses of conversion have to come from the battery. With the inertia starter the battery gives up its energy at a lower rate for a longer time. Nevertheless, there is a saving in battery weight, as it need not be so robust, and its efficiency will be higher at the lower rates of discharge. The additional weight of the flywheel is largely saved in the motor.

Advantages of Inertia Starters

The advantages of this type are :

(1) Lower overall weight of system in relation to the energy provided. Alternatively, where the cables and battery are already standardised in an aeroplane, better starting can be provided.

(2) Rapid rotation of engine, ensuring good induction of explosive mixture.

(3) Excellent operation at low temperatures. The current taken from the battery is unaffected by engine stiffness, as the starter is not engaged with the engine crankshaft until the flywheel has attained operating speed. Consequently the battery and motor cannot be overloaded.

Disadvantages of Inertia Starters

The disadvantages of this type are :

(1) Starting is not so quick as by other methods, as some 15 to 20 seconds are spent in speeding up the flywheel.

(2) A larger torque is applied to the engine crankshaft.

(3) Where aeroplanes are operated between aerodromes equipped with ground-starting equipment (a ground battery of large size plugged in for starting), the inertia starter shows no saving in weight.

An external view of a B.T.H. Type FB Form A inertia starter is shown in Fig. 6. This starter is discussed in detail later in this article.

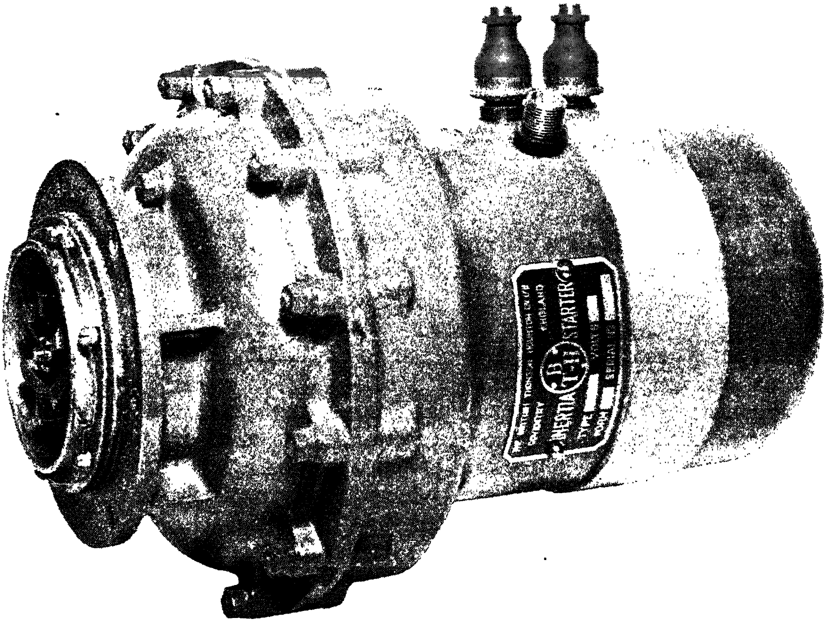

Fig. 6.—EXTERNAL VIEW OF B.T.H. INERTIA STARTER TYPE FA

Alternating Current for Aeroplanes

So far, only low-voltage direct current has been used for operating electric starters, and a knowledge of D.C., together with some mechanical knowledge, is all that the maintenance engineer has required. But the increase in the size of aeroplanes with the corresponding demand for more power throughout the aeroplane is causing investigation into the use of a more efficient power system. The use of alternating current, either single- or three-phase, of a frequency round about 400 cycles is under consideration, and if adopted would show a weight saving in very large aeroplanes, taking the electrical equipment as a whole. Whilst A.C. is not the ideal medium for starters, due to the lower inherent starting torques of A.C. motors compared with D.C., the advantages of A.C. for most other services would more than offset this. The maintenance engineer who takes a pride in his job, and whose experience of electricity has been limited to D.C., would be well advised to make a study of the fundamental principles of A.C. in readiness for the time when the knowledge so gained may be very useful to him. Such a study, however, is outside the scope of this article.

General Notes on Care and Maintenance

In later pages of this article will be given detailed particulars of examples of the apparatus which in broad outline has already been described, together with detailed information relating to maintenance and servicing. Certain observations, however, affecting care and attention can be applied to most electric starters, irrespective of their particular make.

Life of a Starter

The required life of a starter in terms of hours of actual use is very short. For example, 10,000 starts at, say, 15 seconds per start gives an operating time of only 42 hours. Hence, in a properly designed equipment properly used, periodic renewal of worn parts should not be necessary. But starters and batteries are so peculiarly liable to abuse that some attention is often necessary.

Lightness is of such paramount importance in aeroplanes that the designer of equipment is forced to take advantage of the short hours of operation to use stresses in excess of those used in other classes of apparatus, stresses which are quite safe where the apparatus is correctly used, but which do not allow an unlimited margin for misuse.

To obtain minimum weight, the motors, for example, are given a one-minute rating, which should be more than adequate for normal starting, and should allow for several attempts at starting. But in practice with a refractory engine this period is often, although it should not be, exceeded, resulting in excessive temperature rise with consequent danger of melting soldered connections and of bad sparking at the brushes. Overheating of switch contacts may also result.

Lubrication

With fair use, then, very little attention should be required. Most makes of starters are grease lubricated by the manufacturers and no further lubrication is required, but the manufacturers' recommendations should, of course, be followed.

Brushes

The brushes should be examined periodically, and if worn replaced. At the same time it is desirable to apply a Megger test for insulation resistance. Starter brushes have necessarily to be of very low resistance in view of the high currents and low voltages employed, and the brush dust thrown off in the course of use is liable to reduce the insulation resistance of the motor. When applying the Megger the external leads should of course be disconnected.

The insulation resistance of a new motor should not be less than 1 megohm, and in use the motor should not be allowed to have an insulation resistance of less than 400,000 ohms. Should the starter have a lower

resistance than this, it should be removed from the engine and the brush dust blown out by compressed air.

Care should be taken in replacing the cover over the windows giving access to the brushes, as if loosely fitted the motor may no longer be fireproof.

In reconnecting it is particularly important that connections should be firmly made in view of the heavy currents carried and the low voltage available. Rubber covers are usually provided for terminals, and should of course be replaced to guard against accidental short circuits. The same remarks apply to all connections in the starter circuit. Little trouble is normally experienced with the insulation resistance of switches provided their insulation is of non-hygroscopic material, and it is not normally found that the insulation resistance deteriorates with use.

The Starter Battery

The heart of any starter system is the battery, and it is essential therefore that it should be maintained in a good condition. As previously mentioned, in a 12-volt system the voltage on the terminals of the motor is usually of the order of 8 volts, there being a drop of about 4 volts due to the resistance of the cables and the internal resistance of the battery itself. In addition, there will be a further drop in the brushes and windings of the starter motor itself accounting for a further 2 volts, leaving only about 6 useful volts. Thus an additional drop of 2 volts in the battery due to its not being in good condition would reduce the turning speed by one-third. The most common sizes of aeroplane batteries are 25 ampere hours and 40 ampere hours, and they are, of course, of the unspillable type. Ground batteries are larger and heavier and need not be unspillable.

The Chloride Electrical Storage Company, Limited, makers of Exide Batteries, offer the following advice for maintaining their batteries in good condition.

Charging the Battery

In many aeroplanes the demands made on the battery exceed the input available from the generator during flight. Where this occurs, it is necessary to arrange for the battery to be recharged on the bench, and a regular routine for the exchange of batteries after every flight or at fixed periods must be instituted.

Bench charging may be carried out by constant potential methods, utilising equipment such as is commonly found in the larger service stations for automobile batteries, or they may be charged in series circuits at constant current, in which case the charging rate, particularly during the gassing period towards the end of charge, should not exceed the recommended normal rate for the particular batteries concerned.

The former method of charging calls for rather less attention and

enables the batteries to be made available for service more quickly. Constant current circuits should always be used, however, for giving initial charges to new batteries or conditioning charges to any batteries which are in storage.

It is important to ensure that the level of the electrolyte is maintained correctly in every cell. More care in this direction is necessary with aeroplane batteries than with most other types, on account of the fact that tolerances are reduced to a minimum. The levels in batteries charged on the bench should be adjusted towards the end of charge, some further gassing being allowed to ensure mixing of the added water.

Topping Up the Battery

It is essential, of course, to use distilled water or water from a source which has been approved by the battery maker or other competent authority. A battery in an aeroplane on the ground will probably be tilted at perhaps 10° or 15° from the horizontal, and this point should be borne in mind if it is to be topped up *in situ*. The difficulty may be overcome with light aeroplanes by lifting the tail.

Avoiding Corrosion of Terminals and Cables

Connections, cell tops, etc., should be kept scrupulously clean. It is desirable to coat the end terminals lightly with vaseline or petroleum jelly (not grease). If this is done, there should be no trouble from corrosion of terminals or cables. It might be mentioned, however, that overtopping of the cells is liable to result in spillage of acid, with consequent danger of corrosion, as even the totally unspillable type of cell may spill out surplus acid if the level is brought above the correct height.

Batteries which are not in use but have been filled in and charged should not be stored indefinitely without attention, or they will deteriorate. A freshening charge at the recommended rate should be given regularly every month.

Mounting the Battery

The position for mounting the battery varies with different aeroplanes. Various factors, such as weight distribution, have to be considered, but from the battery point of view the most important features are that it shall be so placed that it is easy of access for examination or removal, and that it is not subjected to heat from the engine or any other equipment, or to mechanical strain.

The most popular methods of holding the battery in position are to make use of a light alloy frame engaging with projections in the outside of the container; to use a batten bearing down on the longitudinal centre line of the battery lid and clamped at each end by a long bolt to the floor; or, thirdly, to use a short bolt from the floor at each end of the battery engaging with a projecting lug moulded at the base of the battery

box. All these arrangements are designed to hold the battery securely and to make its removal or replacement simple.

INVESTIGATION OF FAULTS IN STARTER SYSTEMS

The method of investigation of a fault in the starting system will depend on which of the following symptoms is displayed :

(1) Starter turns engine at usual speed, but engine fails to start.
(2) Starter turns engine, but at a reduced speed.
(3) Starter fails to turn engine.

In case (1) the starter is doing its work, and the fault may be presumed to be in the ignition or carburation, and will not be discussed here.

Clutch Slip

In case (2) it should first be determined if the low speed is due to clutch slip. All starters are provided with a slipping clutch, whose function is to protect the starter and crankshaft of the engine in the event of backfire, with the additional function in inertia starters of taking up the drive smoothly. In the course of use the clutch setting may drop, due to wear or engine oil leaking into the starter.

Clutch slip can readily be detected, since the electric motor and gears will run at normal revolutions, and anyone familiar with the particular aeroplane will readily detect, from the pitch of the noise emitted by the gears, whether their speed is about normal. Moreover, with clutch slip the airscrew will tend to go very much more slowly over compression whilst attaining normal speed between compressions.

If the clutch is not slipping, the trouble may be insufficient volts reaching the motor, due to a flat battery or a bad connection or switch introducing resistance in the circuit, an electrical fault in the starter, or, very rarely, a mechanical fault in the starter.

In case (3) the faults may be as in case (2), with the further possibility of an open-circuit in the motor or a faulty control switch or solenoid switch.

Dealing with Clutch Slip

If it is decided that there is clutch slip, it is in general best not to attempt correction, but to return the starter to the makers for correction. Special torque measuring equipment is required properly to set the clutch, and without such equipment the clutch cannot be accurately reset, and if adjusted blindly may be set at so high a value that it does not adequately protect the starter and engine.

In cases of emergency, however, and where the slip is found to be due to the ingress of engine oil (a thinner lubricant than is employed in starters), the clutch plates may be cleaned and lubricated with the correct grade of grease, and the clutch reassembled, taking care the adjustment for the clutch springs is returned to exactly the same position.

Terminal Voltage

If it is decided that the clutch is not slipping, the first step is to determine the voltage at the terminals of the starter. No specific value can be given, but usually the voltage on the starter should be from 7 to 9 volts for 12-volt systems and from 15 to 18 volts for 24-volt systems, according to the wiring and battery, and to the temperature of the engine.

If, with the control switch closed, a voltmeter on the starter terminals indicates the nominal voltage of the system (12 or 24 volts), there is obviously an open circuit in the motor. If the voltmeter reads zero, there is an open circuit in the supply to the motor.

In view of the large cables of necessity used, a break in the actual wiring can be ignored, and a very bad connection, or the failure of the solenoid switch to close would be suspected in the event of no volts reaching the starter. This might be due to a fault in the switch itself, or failure to make contact of the cockpit switch which controls the solenoid switch.

Checking the Solenoid Switch

To check the solenoid switch, connect a lead across the heavy terminals of the switch, and if the starter then operates, it is clear that the trouble lies in the solenoid switch or the control switch. It is often possible to determine which of the two switches is at fault, as solenoid switches close with a snap which can usually be heard, and if heard when the control switch is closed, then the control switch and its wiring must be in order. The noise heard will be that of the magnetic armature closing, but the contacts of the solenoid switch will be so badly burned as to be incapable of passing current.

A fault having been located, should be dealt with as follows. A flat battery should be replaced, but the reason for the battery being discharged should be investigated. Bad connections are easily remedied, but in the case of faulty switches, no general instructions can be given, as they vary so much in type and construction.

Should the fault lie in the starter and be other than clutch slip, the strap or cover giving access to the brushes of the starter motor should be removed and the brushes examined. Make sure that the brushes are bearing on the commutator, and that they are free to move in their holders.

Examine the brush springs to see that they have not lost their tension due to overheating. The actual spring pressure will depend on the design and grade of brush, but should be between 5 and 10 lb. per square inch of brush section.

Examine the commutator and remove any accumulation of dirt or grease, using a cloth soaked in petrol. If this examination does not reveal or correct the trouble, the starter should be removed from the engine.

A starter cannot be readily bench tested, as the means for loading and torque reading are not usually available, but some idea of its performance can be gained by running it light. In this connection it must be borne in mind that starters are always series wound, that is, their fields and armatures are connected in series, in order to obtain large starting torques, and smaller peak currents at the moment of switching on. They have the characteristic, however, of attaining very high speeds at low torques.

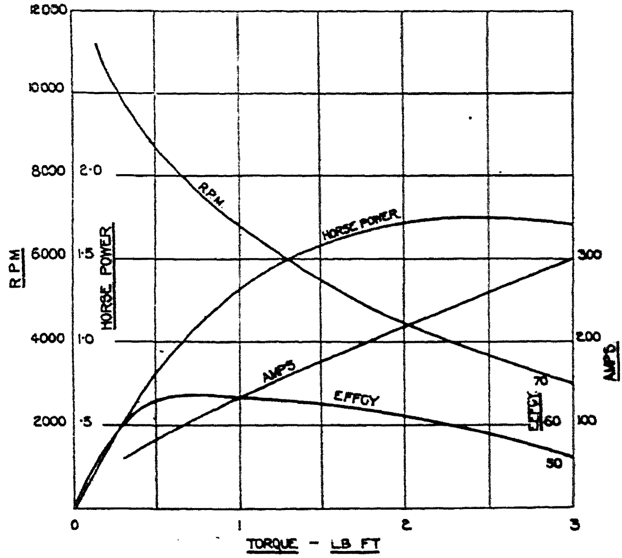

Fig. 7.—Torque curve for B.T.H. type CA 4125 motor

A typical torque speed curve for a starter motor is shown in Fig. 7, from which it may be noted how steeply the speed curve rises at light loads. Full voltage should never be applied to an unloaded starter unless it is of the inertia type, otherwise it may reach a dangerous speed. Normally, about one-third of the nominal voltage should not be exceeded. From the noise, acceleration, sparking, etc., some idea of the mechanical condition can be estimated.

Should a test not indicate the fault, it will be necessary to strip the starter for examination, and where workshop facilities are not available, the starter should be returned to the manufacturers. Where facilities exist, the makers' instructions for dismantling should be followed; and in reassembly the following points should be remembered :

(1) Smear the gears and fill the bearings with the recommended grade of grease.

(2) To smooth a rough commutator, never use emery, as emery dust may get into bearings with harmful results. A dirty commutator may be cleaned with a cloth soaked in petrol, but a rough commutator should be lightly skimmed in a lathe, taking care to keep it true with the bearings on which the armature runs.

(3) Never apply grease or oil to the commutator or brush gear.

(4) All internal connections must be clean and tight.

(5) Brushes must be free to slide easily in their holders.
(6) Brush springs must be up to their correct tension.

MAINTENANCE OF ELECTRIC STARTING SYSTEMS

In the previous pages we have described in a general way the various components of starting equipments. We now give more detailed descriptions, with particular reference to the maintenance of certain individual starters and their accessories.

It has been mentioned that the usual form of starter is one comprising an electric motor, with a gear-box and clutch, and with means for automatically connecting and disconnecting the drive to the engine. In some instances the gearing and clutch are supplied by the engine manufacturer, and may be built into the engine, the accessory manufacturer providing the electric motor and switches.

Armstrong Siddeley Starter

In Fig. 8 is shown in exploded form a starter made by the Armstrong Siddeley Company, and which was shown partly assembled in Fig. 3. The electric motor is not shown. The shaft extension of the motor carries a small sun pinion, which engages with a double planetary gear system that drives a worm shaft. The worm wheel, which is driven by the worm shaft, contains a cone type of clutch, through which the drive to the engine is taken. The worm shaft has an extension for hand operation. The various parts will be followed by reference to the key to Fig. 8.

The total gear reduction is approximately 420/1, giving a turning speed of from 12 to 16 r.p.m., depending on the temperature of the engine oil. It is not always appreciated how big a part oil stiction plays in the resistance of an engine, and it is quite usual for the torque required to turn an engine at –10° C. to be three times that at normal temperatures, and this must be borne in mind when considering the suitability of a given starter for a given engine.

Unlike most starters, this one is lubricated by oil, the level of which should be occasionally checked, and no other attention, other than inspection of the motor, is required unless the clutch in the course of use should ease off. To adjust the clutch, the starter must be removed from the engine, and the driving dog firmly fixed in a vice. Removal of the rear cover S exposes the clutch-adjusting nut R, which is turned clockwise to tighten.

The Motor

The motor type CA 4125 used with this starter is made by the British Thomson-Houston Company, Limited, and is that shown sectioned in Fig. 2, and whose characteristics are shown in Fig. 7. Its component parts are shown in Fig. 9, where alternative spigot fixings and shaft extensions are shown.

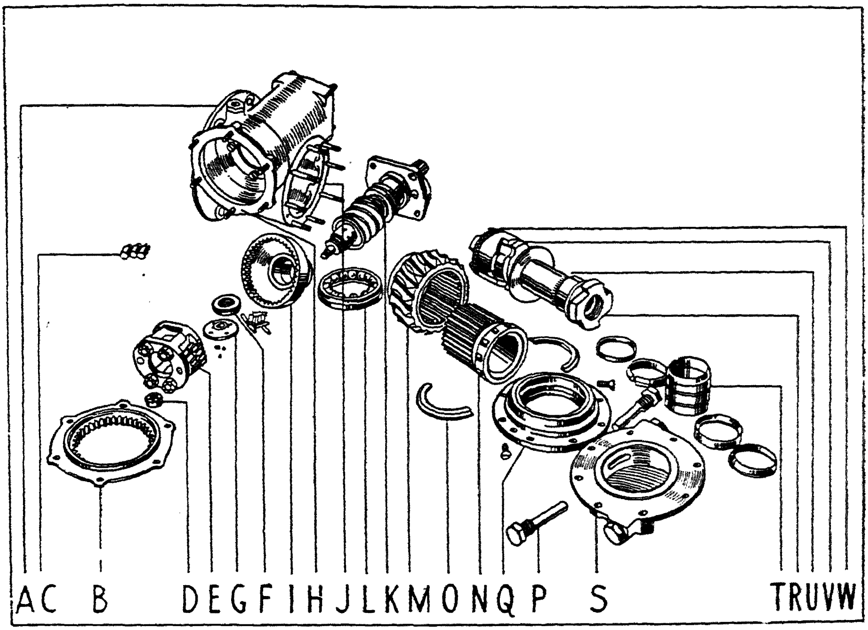

Fig. 8.—Exploded view of Armstrong Siddeley gear-box

It is a four-pole, series-wound, 12-volt motor with four brushes, and for convenience the four field coils are connected in parallel, two being connected to one brush, the other two being connected to the opposite brush, which has the same polarity. The other two brushes are connected in parallel by the plate on which the brush boxes are mounted.

Dismantling the Motor

To dismantle the motor, first remove the cover strap (37) and take out the two screws which secure the field leads to the brush holders, remove the brush springs, and remove the two nuts (57) on the through bolts. The commutator endshield (13) can then be taken away and the armature removed.

Reassembling the Motor

On reassembly, should a new bearing or part affecting endplay be fitted, the endplay should be checked. With the type of bearing used (often referred to as "magneto" bearings) some endplay is necessary, and should be between 0·002 in. and 0·005 in. If this endplay is not obtained, it can be adjusted by fitting a washer (9) of different thickness between the ball bearing and oil baffle at the commutator end of the armature.

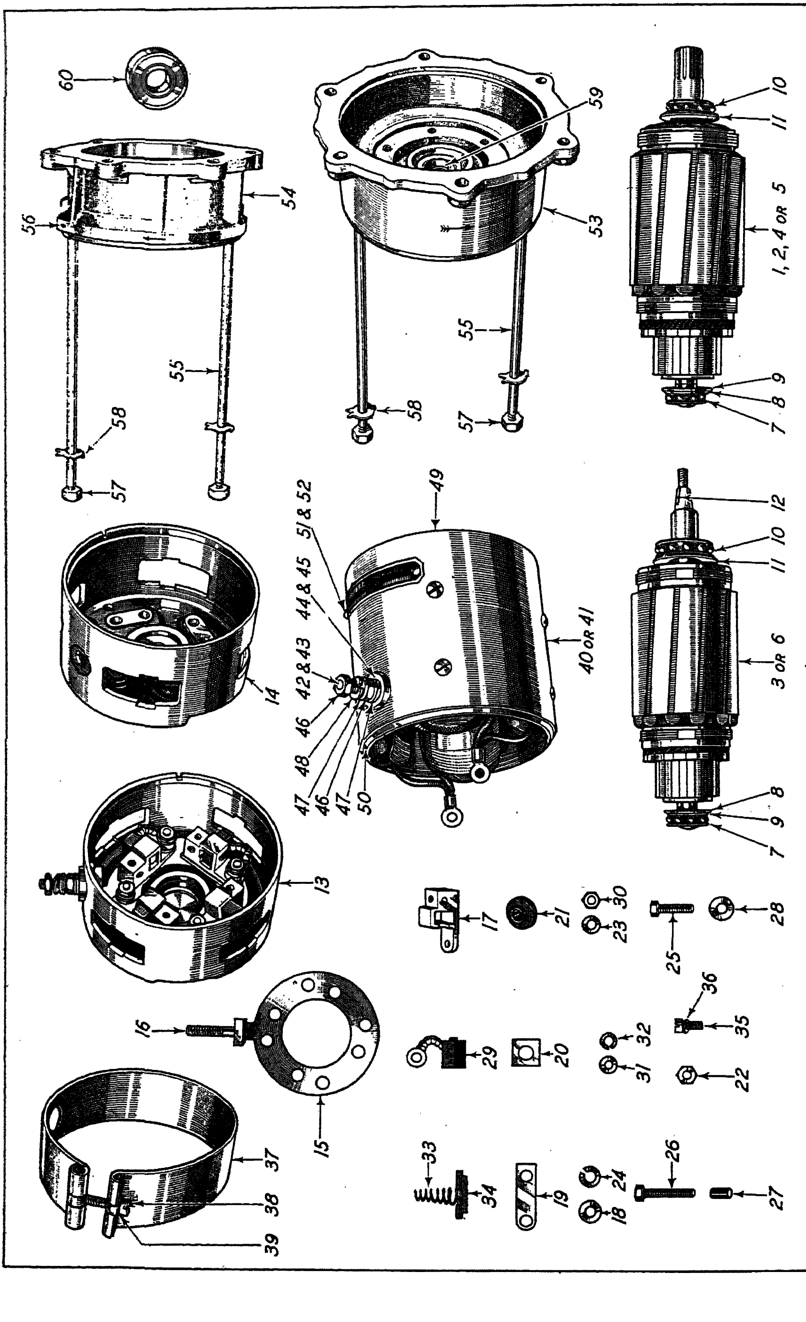

Fig. 9.—EXPLODED VIEW OF B.T.H. STARTER MOTOR TYPE CA 4125

The driving end shield contains an oil seal which bears on the shaft, and care should be taken, in threading in the armature, not to damage the edges of the seal, and it is advisable lightly to smear the portion of the shaft on which the seal bears with oil.

Should it be necessary to resolder a field lead connection tag, a high-melting-point solder, such as three parts lead to one part tin, should be employed, and care should be taken not to burn the insulation of the field coils or leads.

Should it be necessary to replace a brush, only the correct grade of brush must be fitted, as special low resistance brushes are used to carry the heavy currents.

Simple Test after Reassembly

After reassembly the motor cannot be adequately tested without a torque testing stand, but can be run light on a reduced voltage, say 4 volts, when a speed of 7,000 r.p.m. should be obtained. The motor should run steadily and without sparking at the brushes. The commutators of starter motors are "undercut," that is, the mica insulations between copper segments are reduced below the surface of the copper, usually by $\frac{1}{32}$ in. The reason for this is that the brushes employed are not abrasive enough to wear down the hard mica, so that with "flush" micas, as the copper wears, the micas tend to stand proud, leading to bad sparking. The micas are therefore recessed, and the cause of sparking after a reskim of the commutator may be that the recessing has disappeared. The micas can be recessed, using a hacksaw blade, taking care not to scratch the working surface of the copper segments, and finally polishing with fine glasspaper.

B.T.H. Type FA Inertia Starter

Fig. 10 shows a section of the B.T.H. Type FA inertia starter, of which an outside view was shown in Fig. 6. As previously explained, the motor of the inertia starter does not drive the engine directly, but is used to speed up a flywheel to a high speed, the flywheel then driving the engine through the medium of a reduction gear train and friction clutch.

Referring to Fig. 10, the armature A of the D.C. series motor is built up on a hollow shaft B, which is integral with the flywheel C. Keyed to the shaft is a sun pinion D, which engages with a double planetary gear system E. The planet gears also engage with an internal gear F—normally held stationary between the "Ferobestos" plates G—and also with an internal gear cut on the inside of a bell casing H. Because of a small difference in the number of teeth on the two sets of planets, the bell casing is driven at a reduced speed, the overall speed reduction being 200·7 to 1.

The nominal speed of the armature and flywheel at the time of engagement is approximately 15,000 r.p.m.; thus the speed of the bell casing

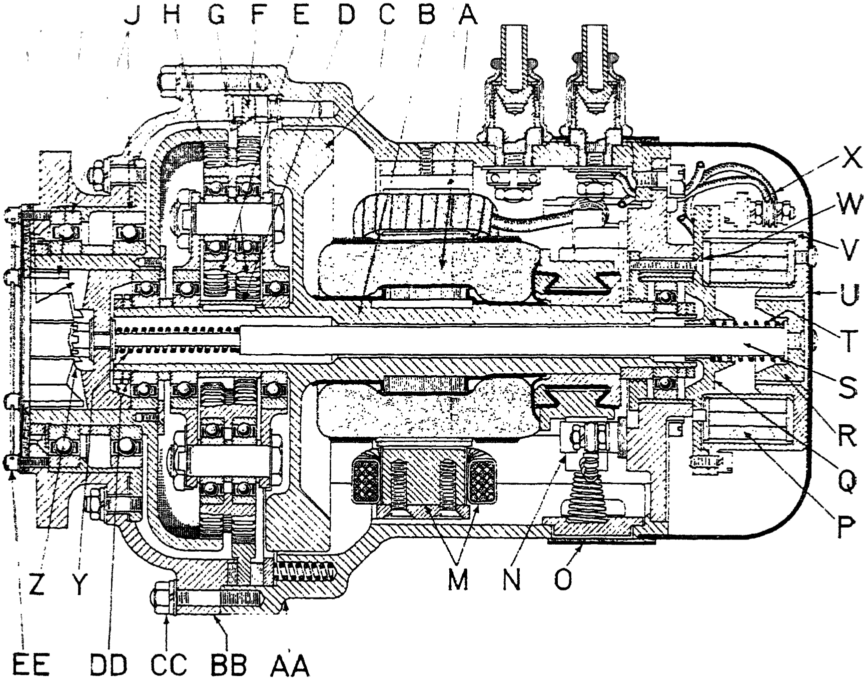

Fig. 10.—SECTIONAL VIEW OF B.T.H. INERTIA STARTER TYPE FA

is 75 r.p.m. The bell casing is carried on two ball bearings J, and is splined at K to drive the engaging dog L.

The motor field system is indicated at M and the brush gear at N.

The engagement of the starter dog with the engine dog is effected by means of a solenoid mounted at the back of the starter. The solenoid consists of a winding P, a pole piece Q, and a plunger R, to which is attached the operating rod S carrying the starter dog L.

To operate, the starter motor is energised by pushing and holding in the starter switch knob for 30 seconds, during which time the motor speeds up the flywheel to 15,000 r.p.m. When the starter switch is released, the bell-gear and dog are running at 75 r.p.m.

The solenoid switch knob is then pulled out, energising the solenoid P, causing the pole-piece Q to attract the plunger R. The operating rod S thus moves towards the engine, engaging the starter dog L with the engine dog. The solenoid switch is released as soon as the engine fires.

Should the jaws of the dogs clash at the moment of engagement, the spring T will be momentarily compressed until the starter dog turns to such a position that it will engage properly with the engine dog. The spring T returns the plunger and starter dog to the normal position when the solenoid is de-energised.

The Ferobestos plates, loaded by a series of springs, together with the internal gear F form the slipping clutch to take up the drive, and to give protection in case of backfire, the internal gear slipping round at a predetermined torque. When the engine is warm, it is only necessary to energise the flywheel for a few seconds.

In a variation of this starter the engagement of the dogs is effected automatically. The sequence of mechanical operations is the same as described above, but the solenoid winding P is connected across the starter-motor terminals, and only one switch is used. On closing this switch, the current is applied to both the motor and the solenoid ; but the latter does not operate immediately, since the initial current taken by the motor causes a voltage drop in the battery and cables.

As the flywheel speeds up, the current decreases and the voltage increases, until, at a predetermined voltage value, the solenoid operates and engages the starter with the engine. The energy already stored in the flywheel "breaks the engine away," and thereafter the starter acts as electrical turning gear, the motor being energised until the engine fires. The switch should then be released. With this arrangement, starting time is reduced.

The starter requires no attention in service beyond occasional cleaning of the commutator with a clean cloth soaked in petrol and examination of the brush gear.

Dismantling the Starter

Should it be necessary to dismantle a starter, the following procedure should be adopted :

(1) Remove screws EE and nut Z, and withdraw dog L and spring Y.

(2) Remove cover U and solenoid leads X, and take off solenoid body V.

(3) Pole-piece Q can then be removed after taking out screws W.

(4) Withdraw the brushes from their holders.

(5) It is desirable to use a jig which clamps the two castings AA and BB together whilst nuts CC are removed. This is because the total pressure of the clutch springs tending to part the castings is more than a ton. In the absence of a jig, the nuts should be each slackened a little in turn so as to keep the load distributed over the studs.

(6) Casting AA having been removed, the locknuts DD are taken off, and the armature and flywheel can be withdrawn from the planet gears.

Reassembling the Starter

Reassembly of the starter is carried out in the reverse order to dismantling, but the following points must be carefully noted :

(1) The clutch plates must be quite dry and free from grease or oil.

(2) The bearings should be lightly greased with "Belmoline" or its equivalent. No oil should be used.

(3) If the planet gear cage has been removed from the armature, when replacing make certain that the planet gears engage with the sun pinion in such a position that the scribed lines (one on each planet gear) are diametrically opposite. This ensures correct meshing of the gears.

(4) In the absence of a jig, the nuts CC must be tightened a little at a time in order to keep the faces of the castings square and to distribute the load of the clutch springs evenly on the studs whilst tightening.

In regard to servicing the commutator and brush gear, the remarks previously given apply, but because of the high speed of the armature, it is particularly important that the commutator should be true and smooth, and that the brush springs are of the correct tension.

Testing General Condition of the Starter

The clutch setting cannot be checked without a torque stand, but the general condition of the starter can readily be checked without any special apparatus. Apply 11 volts to the starter terminals for 30 seconds, by which time the driving dog should attain a speed of at least 75 r.p.m. Then measure the time for the starter to run down. This should be approximately 50 seconds. An electrical fault or mechanical stiffness will prevent the starter reaching the specified speed, and will also reduce the " running-down " time.

To check the dog engagement, energise the solenoid winding, which should require not more than 10 volts to operate the dog. The clutch setting of this starter is nominally 300 lbs./ft., but this can be varied by fitting clutch plates of different thicknesses. At the moment of switching on, the starter takes 100 amps., which rapidly falls to 30 amps. as the flywheel speeds up, and from 20 to 25 starts are obtainable from a 25-amp. battery.

B.T.H. Type CA 3750 Starter

In Fig. 11 is shown in exploded form the parts of a starter made by the B.T.H. Co., Ltd., Type CA 3750, Form FF2, which is similar in general construction to the inertia starter just described, except that since it does not operate on the inertia principle, but drives the engine directly, it contains no flywheel, and does not need a solenoid for engaging the drive, which is taken up automatically as soon as the starter revolves. The dog engagement device is not shown, as it is built into the engine with which this starter is used.

The main parts of the motor, which is similar in general construction to the type CA 4125 already described, are designated by 1 (armature), 34 (field unit), 7 (brush gear end shield) and 45 (driving end shield). On the shaft extension of the armature is mounted a sun pinion (78), which drives two double planet pinions (70). These planet pinions, which have two rows of teeth on one gear, are mounted through ball bearings (71) on bolts (74), fixed in the planet cage (68). This cage is mounted through bearings on the armature shaft extension.

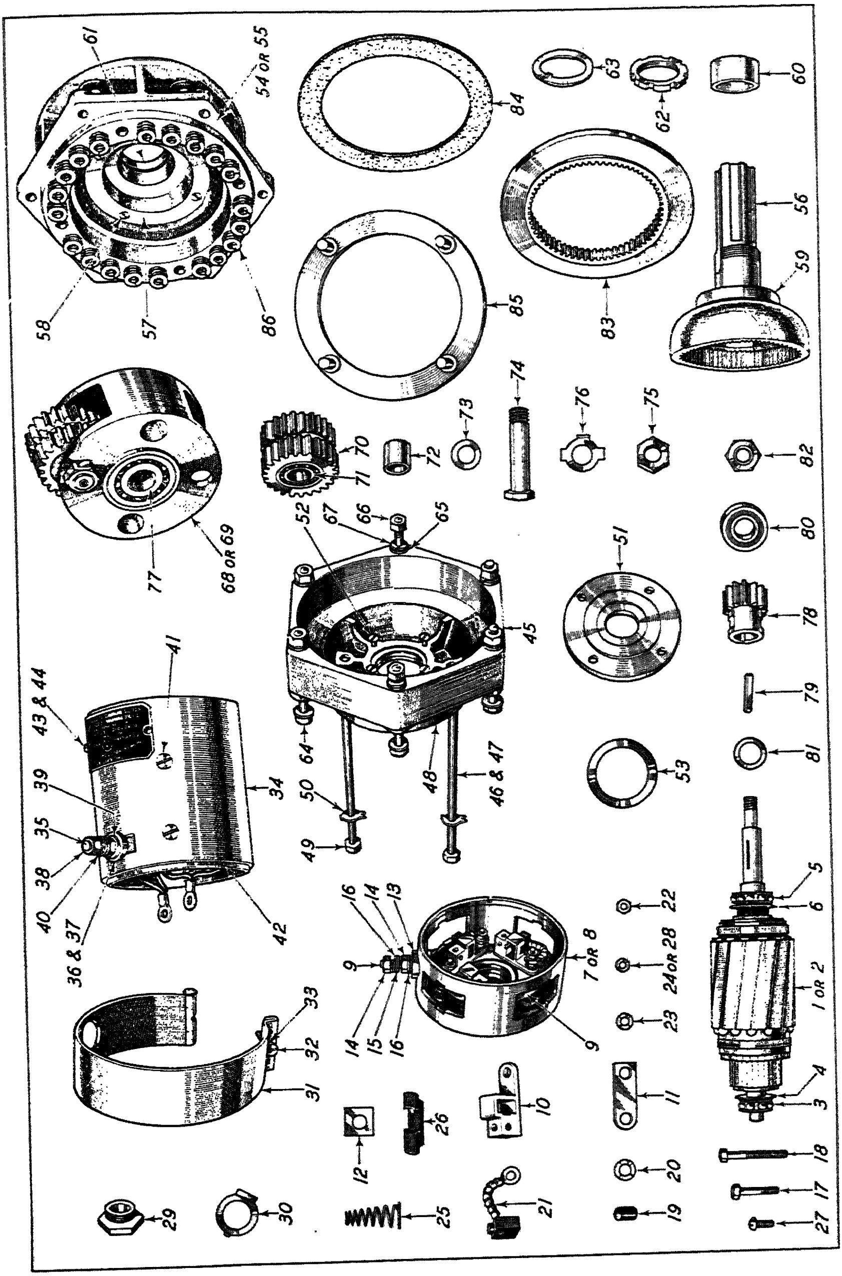

Fig. 11.—EXPLODED VIEW OF B.T.H. STARTER TYPE CA 3750. FORM FF2

One row of the planet teeth runs round the teeth of the "fixed" annulus gear (83). The other row of planet teeth runs round the internal teeth of the bell gear (56). By reason of the different number of teeth on the two planetary systems, rotation is given to the bell gear.

Reference to Fig. 10 of the inertia starter will help in following this description. A double planetary system of this kind gives a large reduction (211 : 1 in this starter) in very compact form. For those not familiar with this form of gearing, we will describe how this large reduction comes about. In considering planetary reductions it is a good plan to imagine the planet cage fixed in space, the "fixed" gear being free to rotate, and see what happens when the planet gears make one revolution on their own bearings.

In this particular starter, the sun pinion has 14 teeth, the "fixed" annulus gear 64 teeth, and the sun pinions mating with them 24 teeth. Then, if the "fixed" annulus was free to rotate, and the planet cage was fixed when the planet makes one revolution on its bearings, the sun pinion would rotate $\frac{24}{14} = 1{\cdot}714$ revolutions in one direction, which we will call positive, and the "fixed" annulus would rotate $\frac{24}{64} = 0{\cdot}375$ revolution in the opposite direction, which we will call negative.

The other set of planet teeth are 23 in number, and the bell gear has 63 teeth. In one revolution of the planets on their own bearings, the bell gear will make $\frac{23}{63} = 0{\cdot}3651$ revolution in a negative direction.

Supposing now we imagine the whole system turned 0·375 of a revolution in space in a positive direction without relative movement of the parts, the net result will be: revolutions of "fixed" annulus $= -0{\cdot}375 + 0{\cdot}375 = 0$; revolutions of sun pinion $= -0{\cdot}3651 + 0{\cdot}375 = 0{\cdot}0099$; revolutions of bell gear $= 1{\cdot}714 + 0{\cdot}375 = 2{\cdot}089$. But this is the true condition, since it is the "fixed" annulus which does remain stationary, and therefore 2·089 revolutions of the sun pinion give 0·0099 revolution of the bell gear. The gear ratio is therefore $\frac{2{\cdot}089}{0{\cdot}0099} = 211$ approximately.

The bell gear has splines shown at (56), which drive a gear mounted in the engine. The gear ratio between the starter and the engine crankshaft is three to one, giving a total reduction from motor to crankshaft of 633 : 1, the cranking speed of the engine being 10 to 12 r.p.m. The clutch setting is 175 lbs./ft., but because of the 3 : 1 gear in the engine, permits a torque of 525 lbs./ft. to be applied to the crankshaft. The clutch effect is obtained by reason of the so-called "fixed" annulus gear being mounted between Ferobestos plates (84), under pressure of twenty springs (86), and the annulus gear slips round under excessive torque.

Dismantling

The method of dismantling is similar to that described for the inertia starter, the casing being first parted by releasing bolts and nuts.

Because of the load of the clutch springs, the use of a jig to clamp the casings together is recommended, but is not essential. In the absence of a jig, the nuts should be slackened off in turn a little at a time. This exposes the gears, and the planet cage assembly can be taken out after removing the locknuts at the end of the armature spindle. This leaves the motor as a unit which can be dealt with as described for the type CA 4125 motor.

Reassembling

Reassembly is in the reverse order, but particular attention must be paid to the mating of the two planet gears with the sun pinion in order that they shall share the load equally. The planets are marked with a spot against one tooth, and with two spots diametrically opposite, and should be meshed with the sun pinion so that a tooth with one spot of one planet meshes with the sun pinion, when a tooth with two spots of the other planet also meshes with the sun pinion. All the spots then lie in a line.

The clutch plates should be assembled dry, and the gears and bearings associated with the gears liberally smeared with Belmoline C grease. The bearings associated with the motor should be lubricated with high-melting-point grease, as a low-melting-point grease might run out and get on to the commutator with harmful results.

B.T.H. Type 04B-1 Solenoid Switch

Fig. 12 is a photograph of the B.T.H. Type 04B-1 solenoid switch partly dismantled to show the contacts. The outside of this switch was shown in Fig. 4, and a sectional drawing is shown in Fig. 13. This switch avoids the need to take heavy cables into the cockpit, and is wound for either 12 or 24 volts. Its contacts are designed to carry 350 amps., and the current taken by the solenoid winding is 5 amps. for the 12-volt version and 2·5 amps. for the 24-volt version.

Referring to Fig. 13, (1) is an aluminium body, containing steel parts (3), (4), and (7), which carry a magnetic flux when energised by the winding (5), and the plunger (6) is attracted to the plate (7), compressing the return spring (36), and causing the copper contact bar (17) to bridge the main copper contacts (24).

It will be noted that there is an auxiliary contact bar (16), to which are riveted two carbon contacts, and the dimensions are arranged so that the carbon brushes reach the main contacts just before the main contact bar (17), and being mounted separately on the plunger spindle, spring (13) can compress, allowing the contact bar (17) to follow up. Conversely when breaking contact the main contacts open first, the carbon brushes finally breaking the circuit.

When contacts carry current associated with an inductive circuit (and the windings of a starter motor have inductance), a high voltage can be induced, causing an arc or spark at the contacts, which is injurious

Fig. 12.—PART ASSEMBLY OF B.T.H. SOLENOID SWITCH TYPE 04B-1.

to the contacts, whose resistance increases with consequent overheating and final failure. The auxiliary carbon contacts are put in to protect the main contacts.

As the switch opens, the main contacts part first, but there is still an alternative path for the current via the carbon brushes, and the arc occurs when the carbons break contact, confining the deleterious effects of the arc to the auxiliary contacts.

When the switch is closed, the current divides itself between the main and auxiliary contacts, but as the carbons have relatively high resistance, practically all the current passes through the main contacts, and any increase in resistance of the auxiliary contacts through burning or pitting in use is of no importance.

Solenoids have the characteristic that, as their airgap decreases, the force exerted increases rapidly. Advantages of this is taken by providing a spring (11), which is behind the main contacts, and permits the plunger to follow up after the contacts are made, reducing the airgap to zero. Under this no-gap condition, the plunger will remain home on a very reduced voltage (which may occur with a flat battery) and will be less susceptible to vibration, and the contact pressure is a fixed and known amount, being the force of the spring (11), and does not vary with voltage. These switches will close on 75 per cent. of their nominal voltage, and once closed will remain so down to 25 per cent. of their nominal voltage. They require no attention in service, being good for many thousands of starts.

Examining the Contacts

Should it be desired to examine the contacts, remove the cover (42), and then the two screens securing the winding leads to the small terminals.

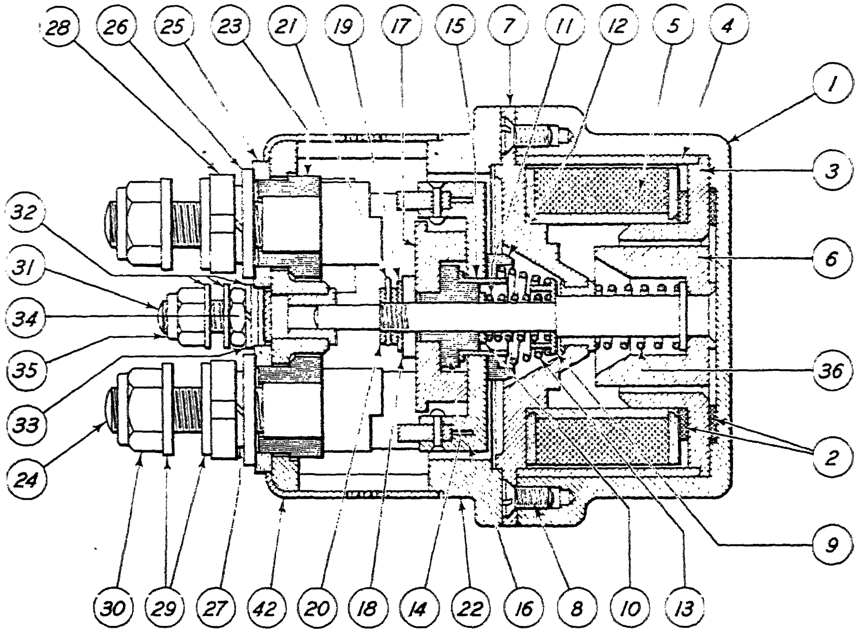

Fig. 13.—Sectional view of B.T.H. solenoid switch type 04B-1.

The winding leads are shown in Fig. 12. On removal of the four screens securing the body (22), the top half of the switch can be taken away, exposing the contacts. After some use, the auxiliary contacts will be blackened and perhaps pitted, but this is unimportant if the main contact surfaces are clean. It is not recommended that the switch should be taken down further, as adjustment of the airgap, etc., may be upset.

On reassembly it is advisable to test the switch. Apply at least 75 per cent. of the nominal voltage to the small terminals, and pass a current through the main contacts. With 350 amps. passing, the voltage drop across the main terminals should not exceed 150 millivolts. Where such a current is not available, a smaller current may be used when the drop should be in proportion.

Do not apply a millivoltmeter to the main terminals until the switch is closed, otherwise it will receive the full voltage of the circuit. The weight of the moving parts is light compared with the forces, and the switch may be mounted in any position without effect on its functioning.

B.T.H. Type N Switch

Fig. 14 is a sectional drawing of the B.T.H. Type N switch, of which a photograph was shown in Fig. 4. This is a double-knob switch, one

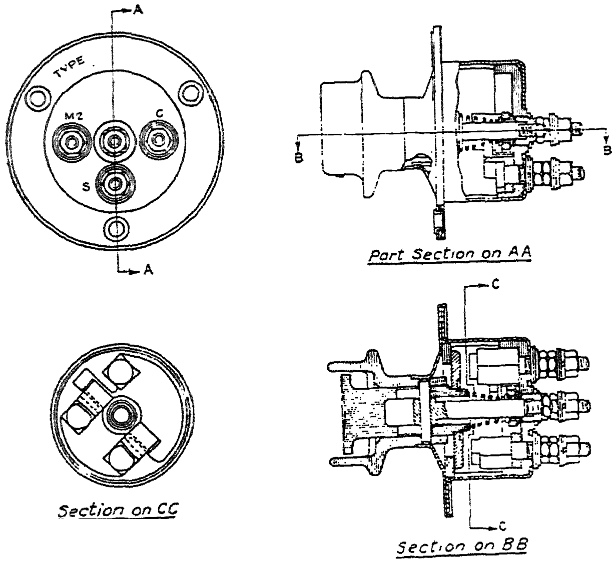

Fig. 14.—Sectional view of B.T.H. switch type N.

knob surrounding the other. The centre knob operates a trembler coil when depressed; the outer knob, when pulled, closes the solenoid switch circuit, which in turn energises the motor. The outer knob has a shroud which prevents accidental operation of the centre knob. The knobs can be operated separately, or together between the fingers and thumb.

To dismantle the switch, it is necessary to drill out the hollow rivets in the flange and to remove the two locknuts at the rear end of the plunger spindle.

On reassembly, the flange having been re-riveted, the locknuts on the spindle must be screwed up just sufficiently to take out endplay in the knobs. The contacts are not sufficiently heavy to carry the full current of the starter, and must be used only in conjunction with a solenoid or relay switch.

B.T.H. Type E1 Ground Socket

Fig. 15 is a photograph of the B.T.H. type E1 ground socket, with the cover removed. This socket and the plug with which it is used were shown in Fig. 5. This item is not only a socket, but an isolating switch, serving to isolate the aeroplane battery when the ground battery is plugged in. The switch blades are clearly shown, and with the cover removed should be clear of the contact face by 1 mm. When the cover is assembled, the spring forces a ledge of the moulded cover on to the tops of the blades, holding them firmly on to the contact face.

In order to insert the plug, the cover must be rotated, enabling the switch to open. On withdrawal of the plug, the cover is rotated by the spring, closing the switch. The switch does not make or break current, it merely carries current when the aeroplane battery is used for starting, and the contacts are therefore not liable to burn, and auxiliary carbon contacts as used in the solenoid switch are not required.

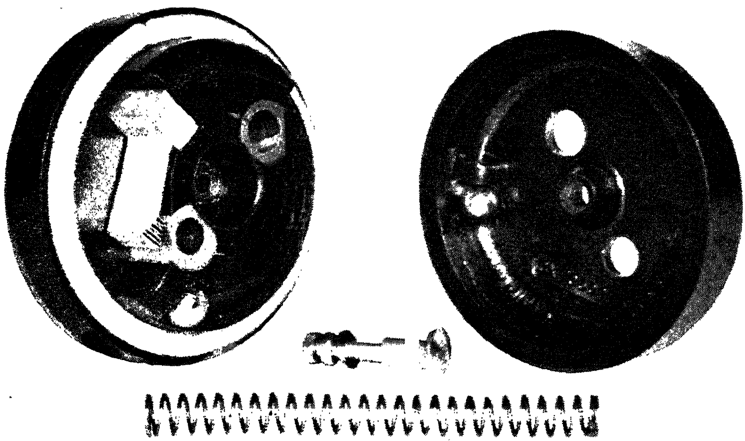

Fig. 15.—B.T.H. SOCKET TYPE E1. WITH COVER REMOVED.

Whilst these notes do not cover every make and size of starting equipment in general use, they cover a representative example of each item of equipment, and although others may differ in construction, the underlying principles are similar, and much that has been said would apply to all equipments.

The chief points of maintenance may be summarised thus:

(1) Batteries must be kept up to the mark, because of the heavy duty demanded of them, and because the starter can only do what the battery will let it.

(2) Connections must be kept tight because of the large currents employed.

(3) Periodic inspection of brushes and commutators, with replacement of brushes and cleaning of commutators where necessary.

GAS STARTERS

NOTES ON CONSTRUCTION, OPERATION, AND MAINTENANCE

THE starting up of a powerful aero engine presents many problems to designers, and all systems at times prove difficult of operation. Amongst the various systems in use is the gas-starter system, which is of great value in the case of the higher horse-powered units.

Principle of Gas Starting

Gas starting of aero engines is accomplished by utilising a combustible mixture of fuel and air under pressure as the initial means of rotating the crankshaft of the engine.

The mixture is fed to each cylinder of the engine during its firing stroke through a gas distributor, which is an accessory of the main engine and driven by it. The cylinders, of course, are fed with the mixture in their appropriate firing order.

During the ensuing rotation the contents of the cylinders are fired by the rotation of a hand-starter magneto, which is connected to the sparking plugs of the engine through the distributors of the main magnetos. In this way the engine crankshaft acquires the necessary rotation to enable it to pick up from its own induction and ignition systems and continue to run.

The Two Types of Gas Starter

There are two methods of gas starting of aero engines, the Bristol or Mark I and the Type A, which was originally known as the R.A.E. Mark II system. The Type A system is superseding the other, so in this article we will concern ourselves only with that system.

The advantage of the Type A system is that it is adaptable to aeroplanes with any number of engines, that it is independent of ground equipment or personnel other than the occupants of the aeroplane so far as the starting of the engine is concerned, and that it is simpler to use and is more easily installed.

Its Construction

The components of the Type A system comprise an air bottle, air pump, hose connection, master cock, press cock, atomiser, primer, and pressure gauge.

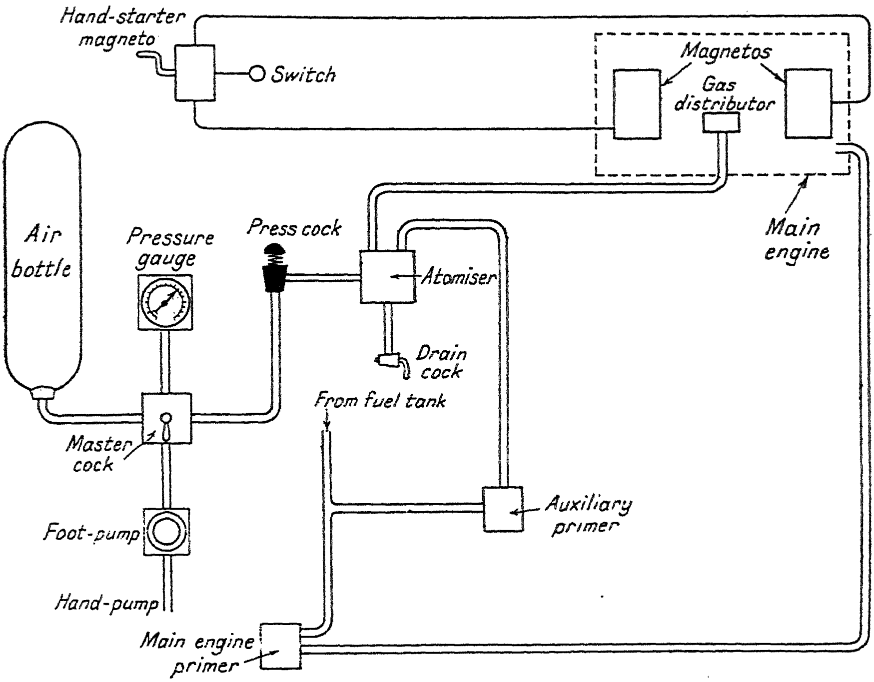

Fig. 1.—Simplified layout of type A gas-starter system

The Air Bottle

The air bottle is a cylinder constructed of 5 per cent. nickel-steel sheet, and is charged with air to a pressure of 200 lb. per square inch. It becomes the energy accumulator of the system and is connected by a pipe to the master cock which controls the air supply to the engine.

The air supply from this master cock is led to the press cock, which is a hand- or foot-operated cock allowing the rapid admission and cutting off of the air used for starting.

The next component in the pipe lead to the engine is the atomiser, the functions of which are those of a carburettor: the air picks up its fuel supply as it passes through the choke and forms the combustible mixture. This mixture is then fed to the gas distributor on the engine, whence it passes to the individual cylinders.

The Primer

In order to fill the atomiser and to prime the induction system a hand-fuel pump is used. If the fuel supply is from a gravity tank, an alternative is to adopt a gravity feed to the atomiser, and this is controlled by a special cock.

The primer consists of a flanged brass barrel, in which works a brass plunger and to which is screwed the valve box. The barrel is internally screwed at one end to take a gland nut. The barrel is flanged and shouldered externally and at the valve-box extremity screwed and coned to seat tightly into the valve box.

The gland nut is of the usual screwed type with a hexagonal head. It is provided with a shallow locknut, and care must be taken to keep the latter and the gland nut in proper adjustment, as the pump efficiency largely depends on absence of leakage at this point.

The plunger is of stout brass tubing, tapped at one end to take the milled-edge disc head which is locked thereto by a taper pin. The other end of the plunger is fitted with a plug which is sweated and pinned therein. The plug has a flange which prevents the withdrawal of the plunger completely outwards through the stuffing box. The body of the plug is screwed, and the end is coned to form a screw-down valve which seats in the outlet branch of the valve box and cuts off the fuel supply to the priming system as required.

The Hose Connection

This is a terminal fitting on the aeroplane, and is usually fitted low on the starboard side of the fuselage, where it is accessible for external connection to the flexible hose from the trolley unit. It is a cast brass T piece, having two flanges on its trunk, the inner providing a means of attachment to the fuselage and the outer forming the plug portion of a quick-release fitting on the end of the trolley-unit hose. The flange has two slots cut in its edge and two ramps leading therefrom milled off the back face. These enable the lugs of the corresponding fitting on the hose end to draw up the nipple to the seat in the conical bore of the hose connection.

Both branches of the T are screwed externally to take all-metal pipe connections, and all three outlets are tapped to take screwed plugs which, when fitted, seat in the conical ends of the outlet bores. One branch of the T is connected to the master cock, the other to the air pump when this is carried as a fixture in the aeroplane ; otherwise it is fitted with a plug. The trunk branch points outwardly and is usually flush with the fairing of the fuselage.

The Master Cock

The fitting next in the pipe line is the master cock, and this is situated in the fuselage within easy reach of the operator. It has four outlets, leading to the air bottle, the press cock, the hose connection, and the pressure gauge respectively. A screw-down valve seating and a spring-operated non-return valve are incorporated in the branches to prevent leaking and to allow of the inward flow only of air. The air-bottle and pressure-gauge connections are always in communication with each other, but are

isolated from the other two branches when the screw-down valve is seated.

The body of the cock is an aluminium-alloy casting having a recessed square base with the main branches bedding in and arranged in a T shape. The non-return valve is cup shaped, enclosing one end of the spring, and has three external guide lands which slide in the bore of the branch to the hose connection.

The Press Cock

This is situated between the master cock and the atomiser, and is operated by foot. Its purpose is to facilitate quick application of the air supply, which is a comparatively slow process with the master cock.

The body of the cock is a funnel-shaped aluminium casting having an outlet branch leading off normal to its main axis.

The Atomiser

This is next in order in the Type A gas starter. It is usually fitted forward of the fireproof bulkhead, and has external branches to the press cock, fuel supply, drain cock, and engine-gas distributor. In multi-engined aeroplanes, this last branch is led to the gas and H.T. distributor, and thence to the engine-gas distributors. The atomiser is a simple form of carburettor, by which the air supplied to it leaves as fuel-air mixture.

The body of the atomiser is an aluminium-alloy casting of inverted cup shape, having a longitudinal ridge at one side and two fixing bosses on the other. The cup forms the fuel reservoir of the atomiser.

The jet is of the usual tubular pattern, with screwed neck and slotted cheese head. The jet orifice is so proportioned as to ensure that the fuel mixture is effective for starting throughout the range of pressures and fuel levels under which the atomiser is called upon to function. The fuel supply in the atomiser will easily outlast the full capacity of the standard air bottle, so there is no need to refill the atomiser each time a start is attempted.

The atomiser is filled by supplying fuel by means of the primer or by gravity feed until it overflows through the stand pipe and drain cock. The source of supply is then cut off, and after the excess fuel has drained away, the drain cock is closed, as directed on the instruction plate affixed to the unit. The flow of air to the gas distributor through the restricted choke causes fuel to spray from the jet into the air stream to form the starting mixture.

Engine-gas Distributors

Each aero engine has its own peculiar distributor, but the principle is the same in each case. A ported disc valve is provided, which rotates at camshaft speed and uncovers holes communicating with each cylinder head in firing order. The port is timed and proportioned so that it opens

to each cylinder during its firing stroke on or just after top-dead centre and closes 10° to 12° before the exhaust valve opens. This proportion ensures that the mixture is not cut off from one cylinder before opening to the succeeding cylinder. In this way continuity of rotation of the engine crankshaft by the application of compressed mixture is assured.

On multi-engined aeroplanes a cock and switch is provided to distribute the mixture from the atomiser and the ignition current from the hand-starter magneto respectively to the individual engines in succession. Three points are provided, enabling up to three engines to be dealt with by one distributor.

Similarly, a special fitting is fixed to the primer, enabling the fuel to be pumped to three engines at once.

Supplying the Air Pressure

As the air pressure is the underlying principle of the whole system, it is essential that the air bottle should be charged to its maximum working pressure and that it be kept at such. The pressure is obtained by means of either a manually operated air pump or else by one operated by foot. The former can be carried in the aeroplane and used at any time, whereas the other forms a useful source of supply on the ground. The air bottle can be brought up to its required pressure in under five minutes and the supply is sufficient for half a dozen starts.

Starting with the Type A System

Starting with the Type A system can be accomplished either by using the air supply from the air bottle only or by starting and charging operations being carried out simultaneously. Where it is essential that the aeroplane should leave its base with the air bottle fully charged, the latter procedure is followed. For normal starting, however, the following procedure can be followed :

(1) Open the drain cock from the atomiser, and fill the fuel reservoir either by turning on the cock from the gravity tank or by unscrewing the plunger and operating the primer with slow gentle strokes until fuel flows from the drain pipe. After allowing the surplus fuel to drain away, close the drain cock, and shut off the fuel supply cock or screw down the primer plunger to its seating.

(2) Turn on the main fuel supply to the engine.

(3) Prime the engine induction system by operating the engine primer pump.

(4) Set the engine controls to the normal starting position.

(5) Turn on the master cock.

(6) Switch on the hand-starter magneto.

(7) Operate the hand-starter magneto by rotating it and depress the press cock with the foot. As soon as the engine fires, switch on the main

magnetos and release the press cock. The engine should then pick up and continue to fire on its own induction and ignition systems.

(8) Turn off the master cock.

(9) Switch off the hand-starter magneto.

Should the engine fail to start, again prime the induction system, operate the hand-starter magneto, and depress the press cock. It should not be necessary to refill the atomiser reservoir for each start; the capacity is sufficient to outlast an air-bottle charge.

Care should be taken to ensure that the induction system is primed sufficiently, as successful pick-up depends on this. Requirements vary with different engines. Climatic conditions too have a distinct bearing on the amount of priming required. In cold weather it will be found that generous priming is necessary, whereas on a very hot day the primer should be used sparingly.

As in the case of a car hand-starter, the press cock should be operated for the minimum period consistent with effecting successful starting in order to conserve air supply. As in everything else, practice makes perfect, and after a short time an operator will know how he can start the engine with the minimum wastage of power.

In the case of multi-engined aeroplanes, it is necessary to make the appropriate settings of primer and gas and H.T. distributors for each engine.

INSTALLATION OF GAS STARTERS

Considerable latitude is permissible in the installation of gas-starter systems, but unless care is taken to follow general outlines, maintenance trouble is liable to ensue. The following procedure is a good guide for avoiding inconvenience and difficulty in maintaining good working conditions.

Air Bottles

The air bottle has only one outlet, and it is therefore desirable to install it vertically with the outlet downwards, so that any moisture deposited within when the bottle is charged may be carried away with the starting air, and accumulations may be avoided which would otherwise deplete the air capacity, and accordingly air pressure. When the bottle is installed otherwise, it should be so sited as to be accessible for easy removal and inspection.

Air Pumps

If the foot pump is carried in the aeroplane and is not a fixture—which it cannot conveniently be in small aeroplanes—it should be well stowed away so that damage to the hose through sharp bends is prevented. It should also be protected from undue exposure to the atmosphere as excessive moisture in the form of rain, snow, and clouds, and excessive

sunlight will cause deterioration. As for the hand pump, it can be fitted in almost any position, the principal consideration to be borne in mind being ease of operation.

There is a grease nipple on the fulcrum pin, and this should be accessible so that lubrication routine may be carried out. The detachable handle should be stowed near the pump.

The Hose Connection

This should be mounted in the fuselage of the aeroplane with its branch for connection to the flexible hose of the compressor unit in such a position as to be readily accessible from the ground ; it should also be flush with the fairing. As the master cock, its neighbouring fitting, is generally placed for right-hand operation, it is as well to mount the hose connection on the starboard side.

If a portable foot pump is carried, the redundant internal branch should be plugged. If the emergency pump is a fixture in the aeroplane, it will be connected to this branch, and the plug will only be needed for insertion in the external branch when the emergency pump is to be used. The plug should therefore be stowed near the pump, together with an instruction plate detailing the procedure for its use.

Without the plug it is impossible to charge the bottle with a fixed emergency pump.

Difficulty is at times experienced in practice in making an effective air seal in the external branch of the hose connection with the plug provided for the purpose, when it is desired to use the emergency air pump fixed in the aeroplane. This is probably due to the fact that the seating in the hose connection wears to conform with the spherical nipple of the flexible hose through repeated application, and so it becomes unsuitable for the conical face of the plug. Leakage at this point entails a proportionate increase in manual exertion at the emergency pump in order to effect replenishment of the air bottle.

In view of this, some of the later installations have the delivery pipe from the fixed emergency air pump connected by means of a T piece into the pipe line, either (i) between the master cock and air bottle, or (ii) between the master cock and press cock. Of these two schemes the latter is preferable, as the master cock can still be used to isolate the air bottle and so conserve its pressure, whereas in the former case reliance is placed upon the non-return valves of the emergency pump to effect this conservation. Hitherto, non-return valves have not proved altogether satisfactory for this purpose, and in such installations frequent inspection of the pressure gauge will be necessary to ensure that these valves are maintaining airtightness. The now redundant internal branch of the hose connection is closed by a plug which is screwed and sweated into position.

The Master Cock

The master cock should be mounted in the pilot's cockpit, so as to be within sight and capable of easy operation by the pilot when seated. The position is generally on the starboard side of the cockpit. The branch of the master cock connecting to the hose connection should be vertical.

The Press Cock

This fitting is generally disposed so as to be operated by the pilot's foot when seated in the cockpit, leaving his hands free for the manipulation of the hand-starter magneto. The button head should be protected, if necessary, against accidental operation by a movable cover. Care must be exercised to connect the branches, so that the air from the master cock tends to close the valve in the press cock.

The Atomiser

This should be mounted near the main engine and at the top of the fuselage of the aeroplane. The fuel reservoir should be so arranged as to be vertical when the tail of the aeroplane is on the ground, as this is, of course, the normal attitude of the aeroplane when starting. This ensures that the fuel level in the jet is correct. The atomiser is normally higher in the fuselage than the press cock, and it is therefore desirable to form a fuel trap in the pipe line connecting the press cock and the atomiser to ensure that when filling the reservoir of the latter the fuel cannot flood the pipe line beyond the trap.

This trap is simply an inverted U formed by the pipe, the apex being taken above the level of the top of the atomiser when the aeroplane is in its starting attitude. The fuel trap should adjoin the atomiser, as a long connection between the two, if flooded, would seriously increase the fuel capacity of the reservoir and cause a substantial rise in the fuel level when the press cock is operated. The fuel-filter plug at the base of the atomiser should be accessible, as it is necessary to remove this to get at the fuel gauze and the jet for cleansing.

In aeroplanes which have an engine mounted in the fuselage, the atomiser is generally installed forward of the fireproof bulkhead, together with the primer and the drain cock used in connection with it. These are usually placed near the bottom of the fuselage on the starboard side suitable for manipulation from the ground. Most of the original single-engined installations were effected in this manner. It is not absolutely essential, however, to adhere to this practice, and the drain-pipe cock and auxiliary primer can be so arranged as to be accessible from the pilot's seat, provided a continuous fall can be fixed to discharge outside the cockpit and at the same time be in view of the operator. An instruction plate should be fixed near the primer and the drain cock.

The Primer

Provision is made for two primers in the aeroplane for priming the engine induction system and the atomiser respectively. The latter is the one which concerns us here, and it is of a screw-down variety.

If it is intended to use the primer from the cockpit, it is possible to use a single primer in conjunction with a three-way cock for both purposes. The primer in either case should for preference be mounted on the starboard side of the cockpit. If it is intended to use it from the ground, the primer and drain cock should be mounted on the starboard side of the fuselage.

As it is necessary to attend to the gland nut from time to time, this should be borne in mind when positioning the primer. Where the fuel system incorporates a gravity tank, a cock can be substituted for the primer feeding the atomiser. An instruction plate should be mounted near the cock giving directions as to its use.

The Pressure Gauge

This should be mounted in the cockpit in a conspicuous position, for preference near the master cock, for it is connected with this and in communication with the air bottle. It should also be in such a position that the personnel responsible for pumping the air bottle from the ground-trolley starter can read it with ease.

The Hand-starter Magneto

The magneto should be mounted in the cockpit in a position where it can be easily manipulated by the pilot's right hand, and the switch should also be mounted near it. Each ignition lead should be connected correctly to the main engine magneto distributors, the L.T. terminal being connected to earth via the starter magneto switch.

The Engine-gas Distributor

It is essential, in the system we are considering, that only the turning port of the rotor controls the air supply to the engine cylinders. If the priming port is present, the hole admitting the air to the port must be closed up by a plug of solder in order to render it ineffective.

The details of the timing of the rotors are given in the respective engine handbooks.

The gas and H.T. distributor in the case of multi-engined aeroplanes should be arranged as shown near the atomiser and equidistant from the engines it is intended to supply. Great care should be taken to ensure that the drain hole in the distributor lies vertically down. The handle should be in view of the operator and within easy reach, and at the same time accessible for removal as necessary, when adjustments are being made to the gland nut.

The primer distributor should be situated centrally and near the gas and H.T. distributor, with the indicating face within view of the operator.

MAINTENANCE

Recharging the Air Bottle

Air bottles should be kept up to full pressure to ensure potential capacity for the maximum number of starts. It is not necessary to recharge to full pressure of 200 lb. per square inch after each start if the pressure has not dropped below the 150 lb. per-square-inch mark, but in this connection it should be remembered that more effective starts are likely to ensue if the pressure is high.

To recharge the air bottles by the trolley unit, the flexible hose is connected to the hose connection and the compressor put in operation by turning the compressor cock to "atmosphere," that is, away from the delivery outlet, the cock at the relief valve "on," and the gas cock in the aeroplane to "atmosphere." Care should be taken to see that the cock beneath the float chamber is shut off so that the compressor cylinder pumps air only. The master cock is turned "on" during the charging operations and "off" when the gauge pressure reaches 200 lb. per square inch.

When bottles are recharged by the compressor unit, no provision is made for shutting off the emergency pump, as this duty is performed by the non-return valves in the delivery branches of the pump.

As the compressor was originally designed to supply air saturated with a fuel-oil mixture at about 80 lb. per square inch maximum pressure, its application to its present duty of dealing with air only at a pressure of 200 lb. per square inch renders its lubrication less effective. Thus overheating ensues if the unit is run for a long period. The normal time required to pump up one bottle to its full capacity is about 45 seconds, and three bottles can be dealt with at one time without danger of overheating.

To charge the bottle with a fixed emergency pump, that is, one connected to an internal branch of the hose connection, the external branch of this component must be plugged with a screw plug, which is generally stowed near the pump. The master cock should then be turned on and the pump operated until the bottle is sufficiently charged to effect a start. In this case a pressure of 80 lb. will be found sufficient to effect a start. After charging, the master cock should be turned "off" and the plug removed and stowed away.

If a portable foot pump is being used, all that is necessary is to mount the pump on the ground near the aeroplane and screw into the external branch of the hose connection the wing-headed fitting at the end of the rubber hose connected to the foot pump, turn the master cock to "on," and operate the pump until the desired pressure is obtained. After the start, turn the master cock "off" and remove and stow the pump.

General Maintenance

Examine the installation generally, and eliminate all leaky joints: those in the pipe line can be effectively sealed by administering a little gold size to their contact faces. The plug and base of the atomiser should be kept tight, together with the fuel pipes feeding and draining it.

Stuffing-box Glands

Stuffing-box glands are disposed on several components, and should receive regular attention to keep the system fuel- and airtight.

Leaky Non-return Valve in Master Cock

A leaky non-return valve in the master cock can be detected by opening the cock, placing a finger over the hose connection inlet, and ascertaining if a pressure builds up. This will indicate some defect in the non-return valve which needs rectifying. The diametrical clearance of this valve in the branch should also be checked, as the valve material is comparatively soft and liable to swell or spread after a period of use and a serious restriction. This will render the work of replenishing the air bottle by the emergency pump in particular unnecessarily laborious. The diameters of the branch and valve are 0·58 in. and 0·55 in. respectively. See that all cocks are in working order, and adjusted so that vibration will not affect their settings.

Timing of Gas Distributor

Check the timing of the gas-distributor turning port for opening and closing. The correct timing is given in the engine handbooks, but as a general rule the port must open on or after T.D.C. and close before the exhaust valve opens.

Non-return Valves in Main Engine Cylinders

The non-return valves in the main engine cylinders should be periodically removed, examined, and cleaned with paraffin, and finally immersed in thin lubricating oil before replacement. Very little trouble will ensue if these valves are brought into frequent operation by the use of the gas starter: it is when the alternative methods of starting are habitually employed that the valves become carboned up and sticky.

Emergency Hand Pump

Lubricate the emergency hand pump with engine oil after every ten hours' flying time, and the foot pump with lubricating oil. Protect the end fitting of the foot pump, if for use on the ground, with a sleeve of rubber tube: this will obviate damage when handling the fitting between times of use and stowage.

The emergency hand pump and the foot pump should both be used occasionally in order to ensure that they are in working order.

The main point to watch for in the case of the two-stroke engine is that a fuel-oil mixture of the correct proportions is used when running. Keep the unit clean externally.

The glands of the crankcase of the compressor unit should be examined if the fuel-oil mixture is found to be leaking excessively from the crankshaft bearings, and the spring washer renewed if necessary. Fit new packing washers to the joint faces of the compressor unit to replace any cracked or otherwise defective, as leaky joints seriously affect the running of the two-stroke engine.

The power cylinder should be decarbonised at intervals, care being taken to remove the deposit which forms at the port edges. The cock and valves in the compressor cylinder need occasional attention to remove any dirt which may accumulate there.

It will be found that the compressor unit is not critical in its settings, and will perform satisfactorily for long periods between overhauls if attention is paid to the essential points enumerated above.

AIR COMPRESSORS

THE use of air compressors for engine starting is not now so extensive as it used to be, the system being replaced very largely by inertia or electric starters.

Usually the compressed air is obtained from an engine-driven compressor which is used to charge an air bottle, but in the absence of such a compressor, the bottle may be charged on the ground, although this is obviously a restriction on its use.

Two types of air compressors are made by the B.T.H. Co., both being single-stage reciprocating compressors, one with a single cylinder and the other with two. They are driven continuously, and maintain a constant pressure in the air bottle. When the maximum pressure is attained in the bottle, the compressor cuts out and idles until the pressure falls.

The Type AV air compressor is a single-cylinder, single-stage model, weighing only 4½ lb., and has a piston displacement of 0·368 cu. ft. of free air per minute at 1,200 r.p.m. Its power consumption is 0·175 h.p. at 200 lb. per square inch pressure. It is designed to raise pressure from atmosphere to 200 lb. per square inch in a standard air receiver of 400 cu. in. capacity in ten minutes, when running at 1,200 r.p.m.

The Type AW air compressor is a double-cylinder, single-stage model, and it is similar in general design to the type AV model, but double the capacity and weight.

OPERATION

By the upward stroke of the piston A, Fig. 1, air is drawn by way of an automatic inlet valve B into the crankcase.

Then the downward stroke of the piston compresses the air, and on reaching the bottom of its stroke, a transfer port C in the cylinder D is opened, allowing the air to be transferred from the crankcase into the cylinder D.

The air is now further compressed, and passes through a delivery ball-type valve E of the main valve unit (an enlarged view is shown in Fig. 2) into the air receiver by the next upward stroke of the piston.

When the receiver reaches the pressure for which the spring-loaded relief valve F is adjusted, the back pressure from the air receiver acting upon this valve causes it to open and enables the air to bypass through the holes G in the valve body and holes H in the compressor body into the crankcase.

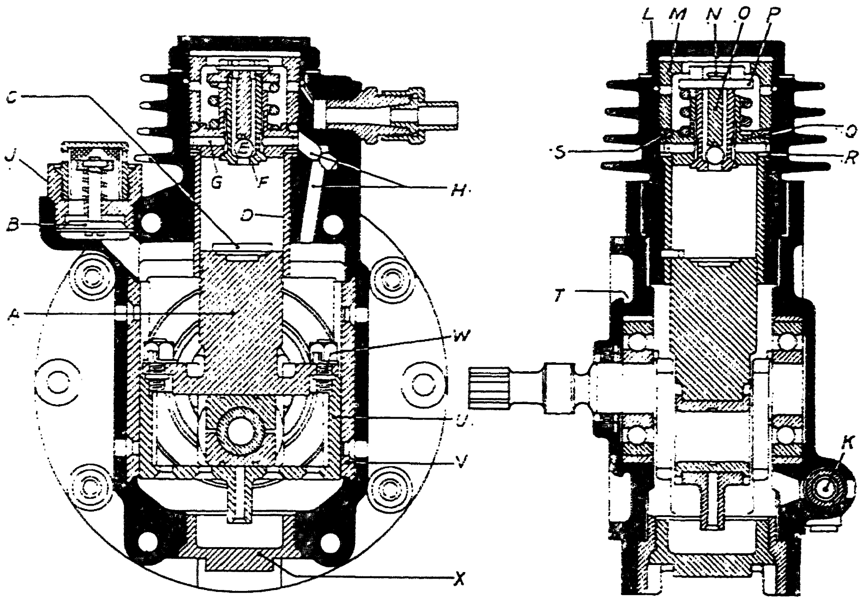

Fig. 1.—Cross-section through a typical air compressor

Under these conditions the compressor cannot generate any pressure, because the air in the crankcase and cylinder is circulated through the circuit described above.

A separate oil container holds a proportionate quantity of oil, through which air is pumped, so that upon the valve cutting out, the back pressure on the oil forces oil along the delivery pipe to the compressor head, thus effectively sealing the ball valve E.

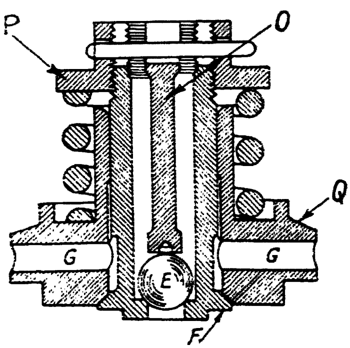

Fig. 2.—Enlarged cross-section of the main valve unit

INSTALLATION

A typical installation is illustrated in Fig. 3.

The compressor must be installed in a vertical position, and mounted in such a position that it will be naturally cooled; alternatively, artificial cooling should be arranged so that the temperature of the cylinder head is limited to 50° C. (122° F.). Excessive temperature causes the formation of carbon, it also causes the lubricant to be pumped away too quickly.

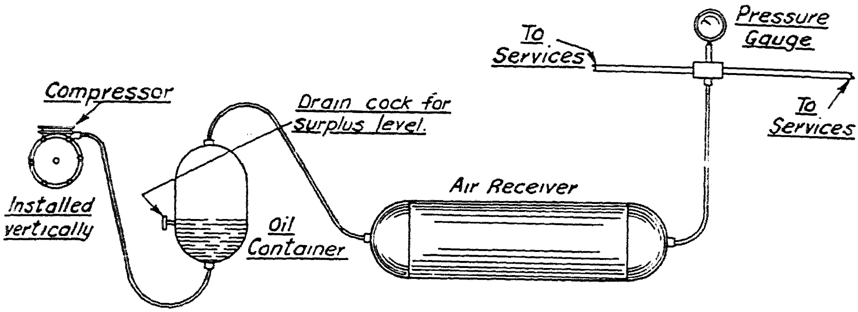

Fig. 3.—A TYPICAL AIR COMPRESSOR INSTALLATION

The compressor should run at 1,200 r.p.m. at normal engine speed. The maximum permissible speed for short periods is 2,000 r.p.m.

The oil container, of $1\frac{1}{2}$ pints' capacity, should carry only $\frac{1}{2}$ pt. of oil (Specification D.T.D.72). Air is pumped through the oil, and the back pressure, acting upon the oil, seals the ball valve E, Fig. 1, against air leakage. This container should be installed slightly below the compressor, so that when changing or cleaning the valve the oil does not drain away.

The air receiver may be installed either horizontally or vertically. Where it is necessary to bring the air into contact with apparatus having india-rubber parts, it is advisable to install an air filter in the pipe line leading from the air receiver to this apparatus.

A non-return valve *must not* be introduced between the compressor and the air receiver, as it is unnecessary, and will prevent the compressor from cutting-out.

LUBRICATION

Type AV Compressor

The sump in this type should be primed with approximately 20 cc. of oil to Specification D.T.D.72.

Oil can be poured in the sump by first removing the air-inlet valve J, Fig. 1, using a standard $\frac{5}{8}$-in. Whit. spanner.

Now depress the plunger K of the oil-level indicator, and oil should appear. In no circumstances should this level be exceeded.

The general indication that insufficient oil is being splashed on to the piston is observed by the compressor failing to reach its set pressure. The oil level in the compressor should be checked.

One filling of oil is usually sufficient for 10 hours' running. If, after having ascertained that the oil level is correct, the pressure still fails to rise, or rises very slowly, the system should be checked for leakage. This may be carried out by brushing thin oil or soapy water over all joints and connections. It should be borne in mind that the smallest air leakage will prevent the pressure from rising.

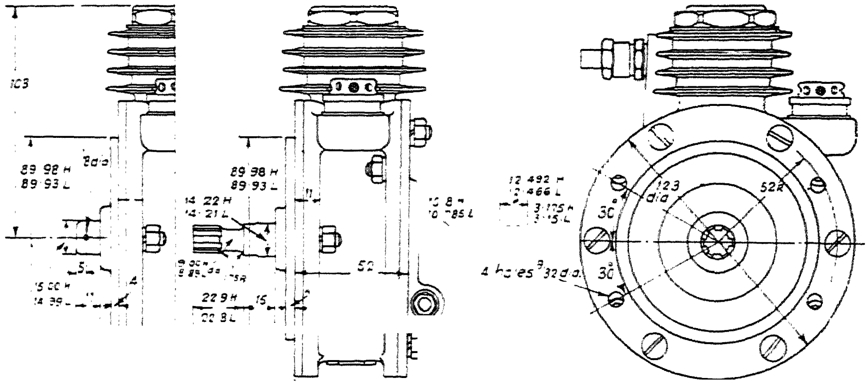

Fig. 4.—DIMENSIONS OF AV COMPRESSOR

Type AW Compressor

The sump in this type should be primed with approximately 40 cc. of oil to Specification D.T.D.72.

The crankcases have an oil passage between them, so that the oil may be poured through either of the inlet valves, but when operating the oil-level indicator, time must be allowed for the oil to distribute itself evenly in the two crankcases.

MAINTENANCE

The installation should be checked periodically to ensure there is no leakage at any part of the system.

Lubrication

The compressor should be lubricated every 10 hours of actual pumping time, in accordance with instructions previously detailed. It is recom-

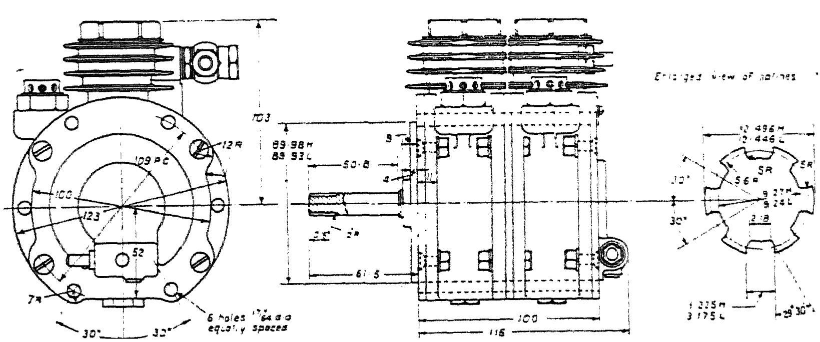

Fig. 5.—DIMENSIONS OF AW COMPRESSOR

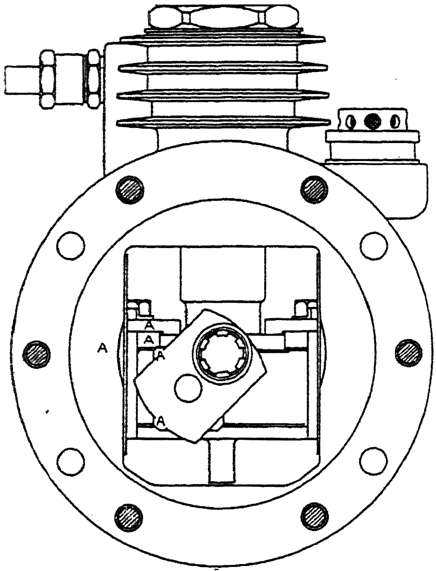

Fig. 6.—Identification markings to aid in reassembly of Type AV compressor

mended that after every 100 hours' running time, the oil level in the oil container should be checked, and surplus oil should be drained off.

Overhaul of the Main Valve

Before attempting to remove the compressor main valve, Fig. 2, the pressure in the air receiver must first be released.

Then remove the hexagon nut L, Fig. 1, and by means of a special external box spanner remove steel locking ring M, Fig. 1. Remove the split pin N, and unscrew the ball-lift stop O. The valve extractor can then be screwed into the valve F, and the valve assembly withdrawn from the compressor head.

Before removing the spring-retaining nut P, its position must be carefully noted, so that it can afterwards be reassembled to the same position, ensuring the same cut-out value.

Having removed the spring-retaining nut P, the valve F can be removed from the body Q ; should there be any carbon deposit or foreign matter on the sliding portion of the valve or ball seating, it should be carefully removed with a cloth soaked in petrol.

On reassembling the valve, the working parts should be smeared with oil (Specification D.T.D.72). The spring-retaining nut must be returned to its former position, and the ball-lift stop carefully adjusted. This adjustment, which is very important, should be carried out in the following manner. The stop must be screwed down so as to touch the ball, and then turned back between $\frac{1}{6}$ and $\frac{2}{6}$ of a turn, bringing the slot in it in line with a slot in the valve. The split pin N should then be replaced.

The copper washers R under the valve should be cleaned, and care must be taken to see that all washers are replaced, as the total thickness of these washers determines the clearance between the piston and the valve.

These washers are provided in different thicknesses, so that this clearance can be accurately obtained. Should it be necessary to renew any of these the total thickness must be the same as the total thickness taken out. The clearance between the valve body and the piston at the top of its stroke should be 0·05–0·10 mm.

The copper sealing washer S must be handled with care, and if dis-

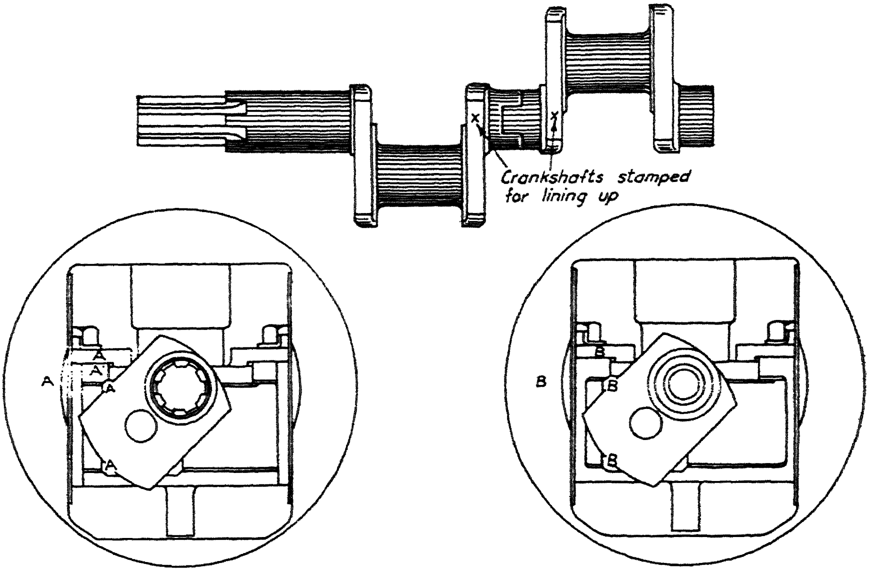

Fig. 7.—Identification markings to aid in reassembly of Type AW compressor

torted should be renewed. The locking ring M must be screwed down very tightly, and it may be found advisable finally to tighten after the compressor is warm.

Fitting New Main Valve

When it is desired to fit a new main-valve assembly, the compressor should be removed from the engine in order to check that the piston does not foul the new valve when at the top dead centre.

Care should be taken to assemble the same adjusting washers under the new valve. When in position, turn the compressor by hand to check that the piston does not foul the valve. If it is felt that the piston does foul the valve, the adjusting washers should be removed and a new combination of washers selected having a total thickness of 0·003 in. greater than those originally used.

DISMANTLING OF COMPRESSOR

This can be done in the following manner. Remove the nuts and screws securing the driving end plate. Extract the driving end plate that is arranged to engage with recess T, Fig. 1, in the end plate, care being taken not to damage the oil seal when passing it over the splines of the shaft. Then, by means of a fibre drift, the opposite end plate can be tapped off. The crosshead U can then be rotated in the guides V so as to make the crosshead nuts W accessible.

After these have been removed with the aid of spanner, push the piston up into the cylinder, when it will be found that the crosshead is easily removable.

To facilitate assembly of the crankpin bearings in the same positions, the parts are lettered in accordance with Fig. 6 for the Type AV compressor, and Fig. 7 for the Type AW compressor, and these should be worked to when reassembling.

It is also advisable to use the protection sleeve T.7 to protect the oil seal. This is slipped over the shaft extension when assembling the driving end plate, and afterwards withdrawn.

In reassembling the Type AW compressor, it should be noted that the two halves of the crank must be assembled so that the crankpins are at 180°, as indicated in Fig. 7.

Should it be found necessary to remove the inlet valve, the inlet-valve gauze cover should be removed, and the inlet valve body with a standard $\frac{5}{8}$-in. Whit. spanner. To remove the base plug X at the bottom of the compressor, use the special tool provided for the purpose.

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